Probing the low-x structure of nuclear matter with diffractive hadron production

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Nuclei as heavy as bulls through collision generate new states of matter

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Outline

Motivation: low-x is a novel exciting regime of QCD:

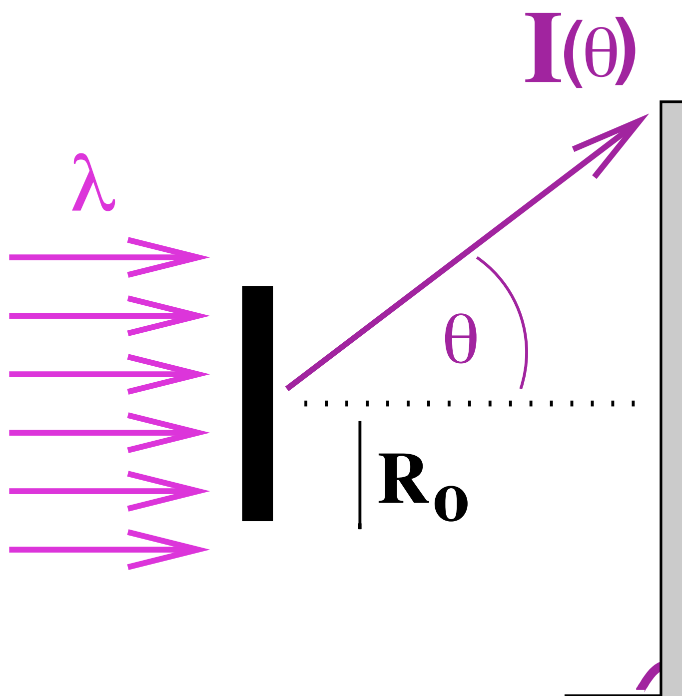
- strong classical Gauge Fields ↔ nonlinear QED
- decay of CGC ↔ quantum tunneling, QGP formation, Early Universe etc.

Evidence for gluon saturation in ep DIS (diffraction, geometric scaling etc.) and in pA and AA at RHIC (inclusive processes).

There are many *open questions* about the dynamics in *transition regions*, validity of the mean-field approximation, NLO effects etc. NEED MORE QUANTITATIVE STUDY!

Study of diffractive hadron production at EIC can provide important insights

Diffraction

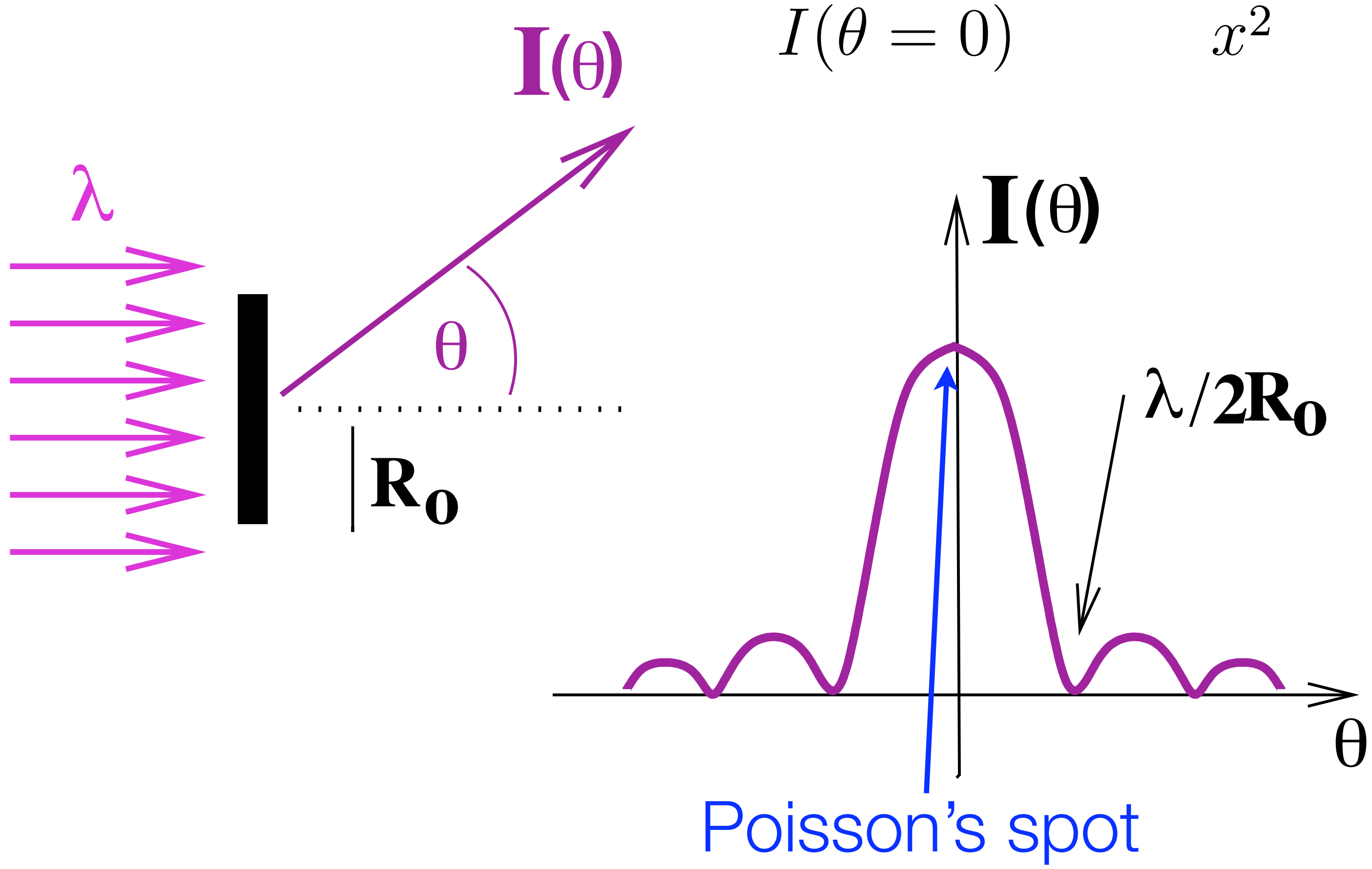


What are you going to see on a distant screen?

fig. courtesy by Arneodo and Diehl

Diffraction

$$\frac{I(\theta)}{I(\theta=0)} = \frac{[2J_1(x)]^2}{x^2} \approx 1 - \frac{R_0^2}{4}(k\theta)^2$$



$$\theta_{\text{min}} = \pm\frac{\lambda}{2R_0}$$

fig. courtesy by Arneodo and Diehl

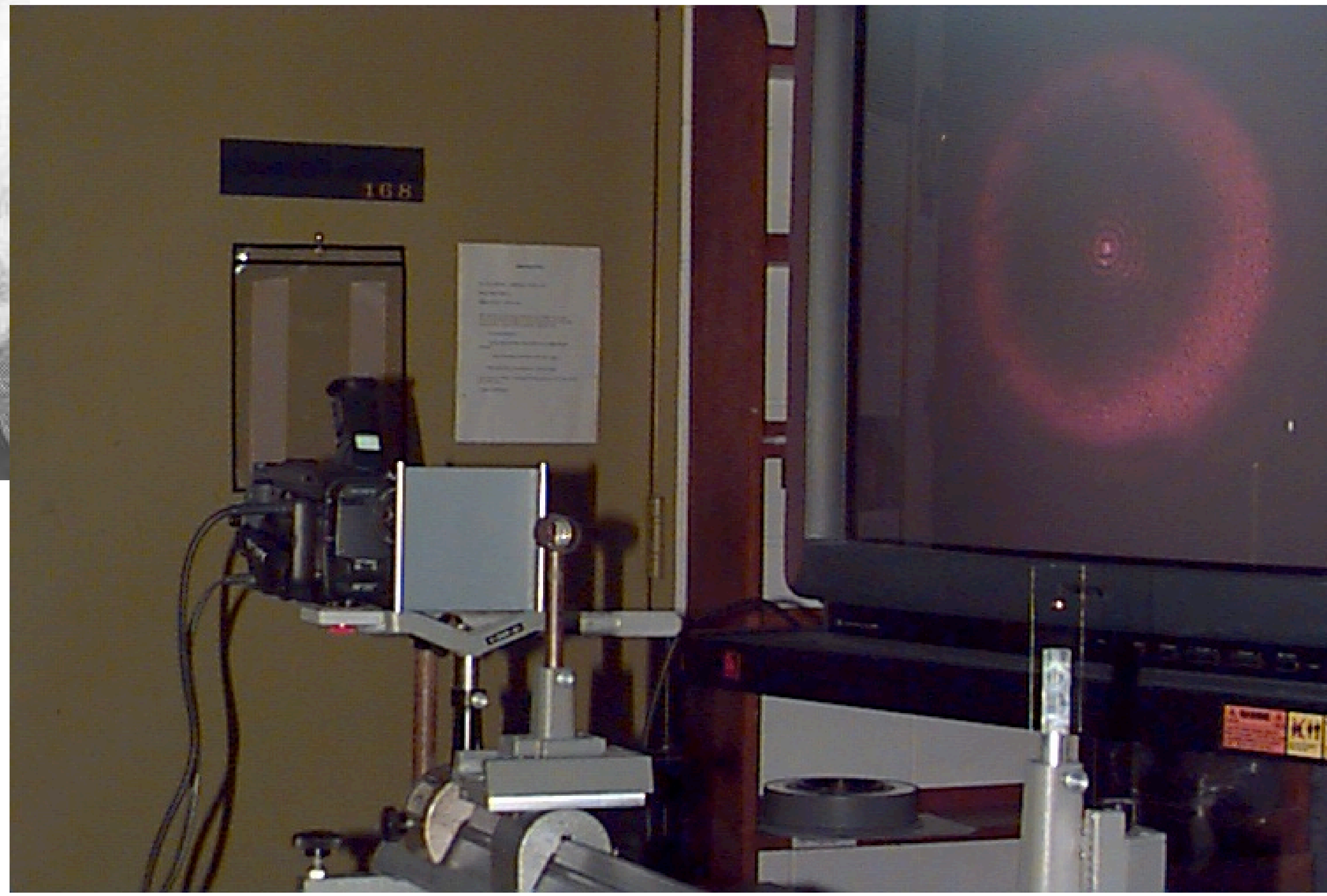
Diffraction: light is a wave! (1818)

Fresnel

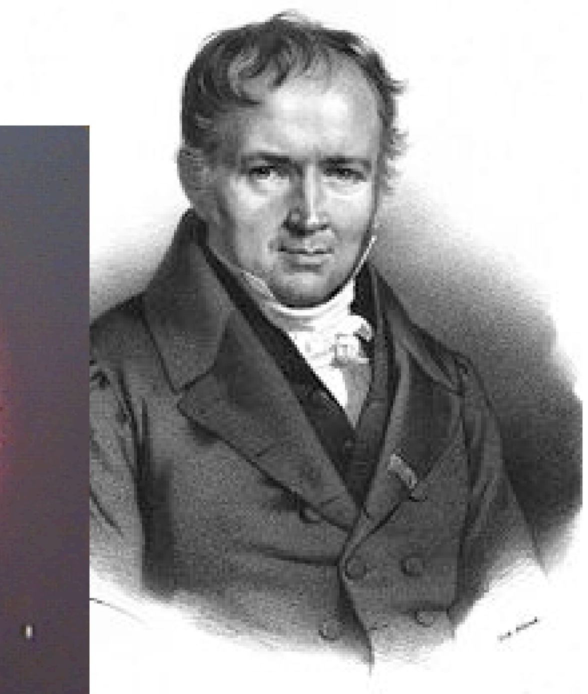
Poisson

Diffraction: light is a wave! (1818)

Fresnel

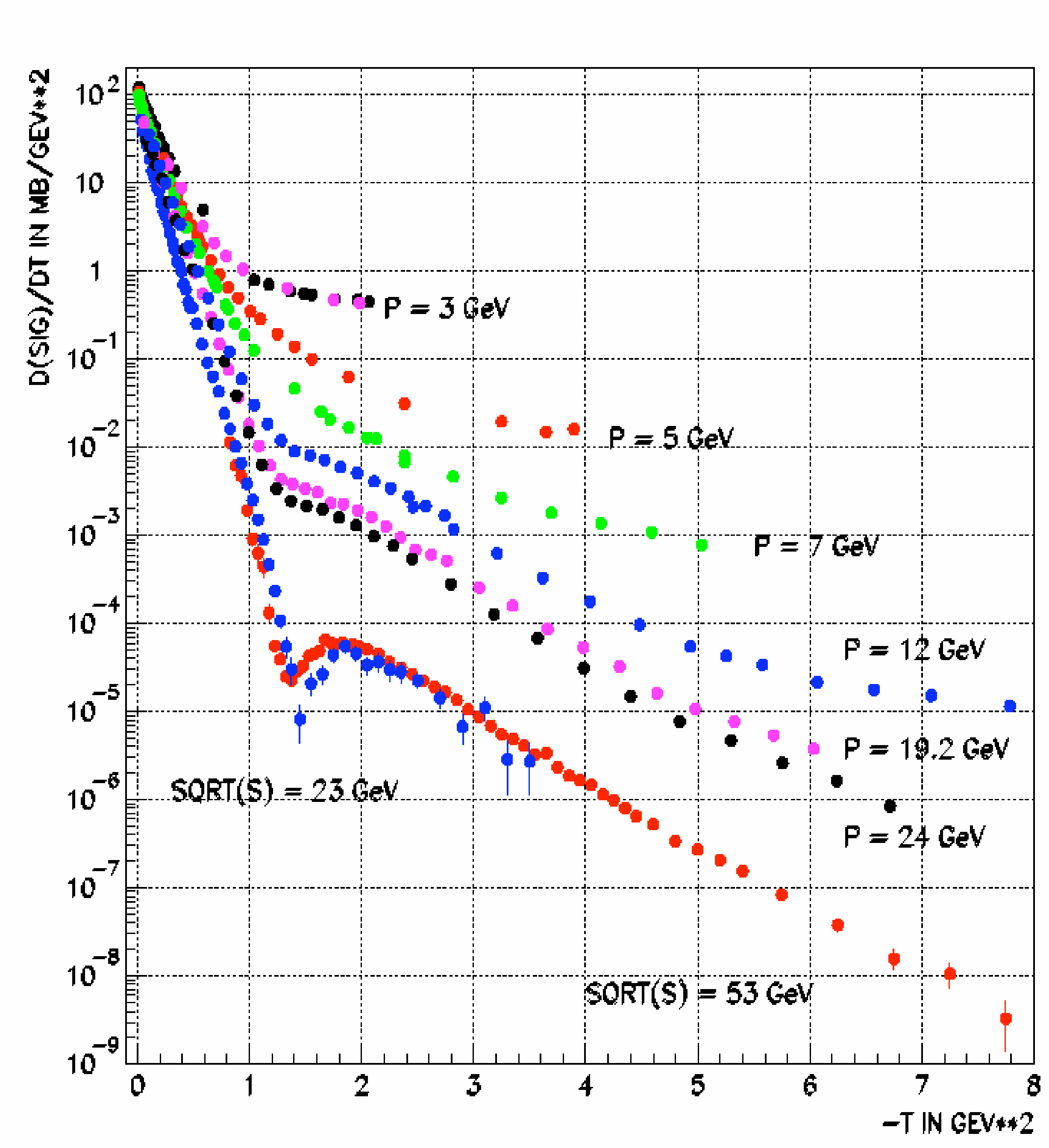


Arago experiment



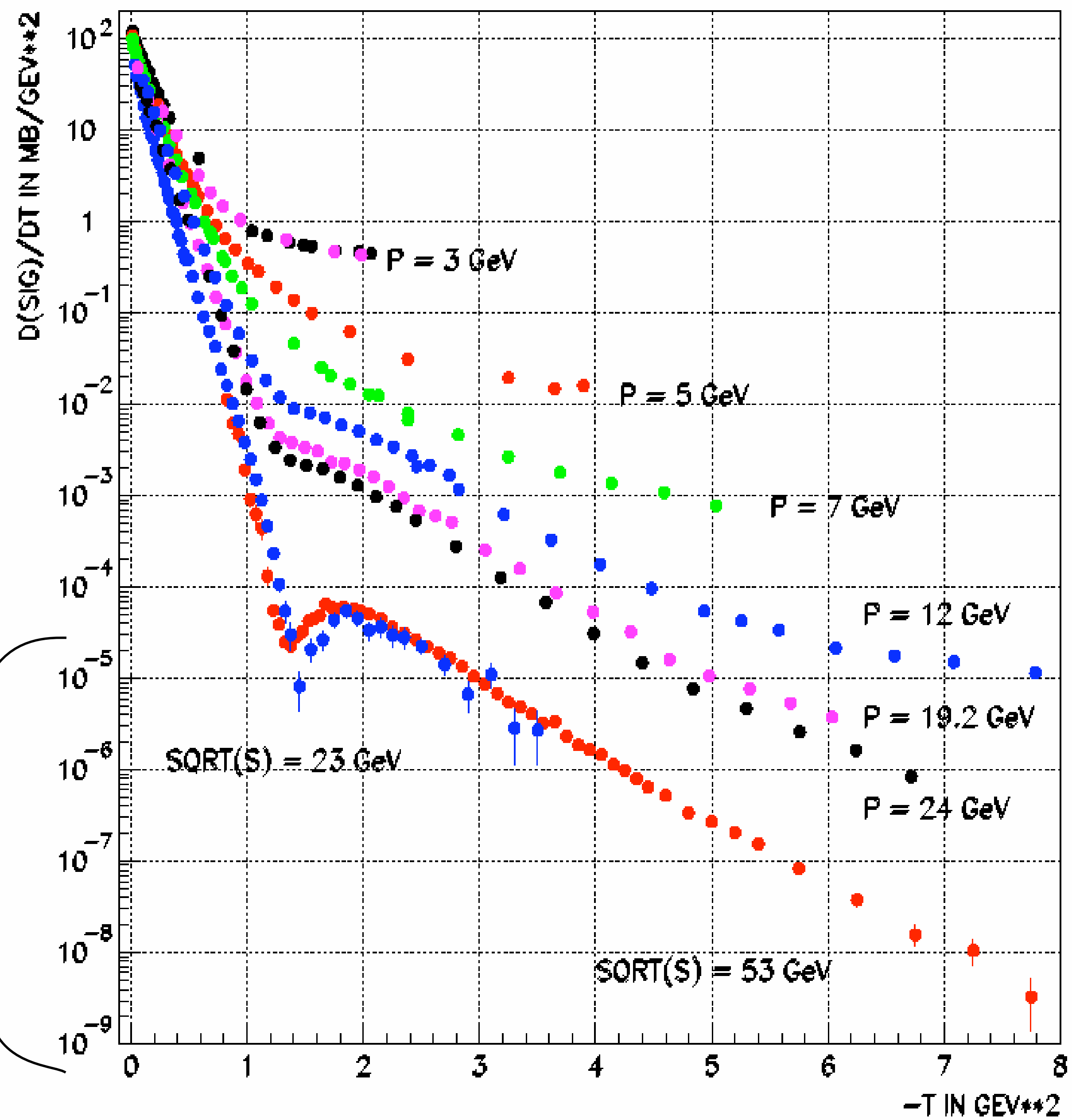
Poisson

Diffraction in pp collisions



Elastic pp scattering

Diffraction in pp collisions



proton isn't completely opaque

Elastic pp scattering

Diffraction in particle physics

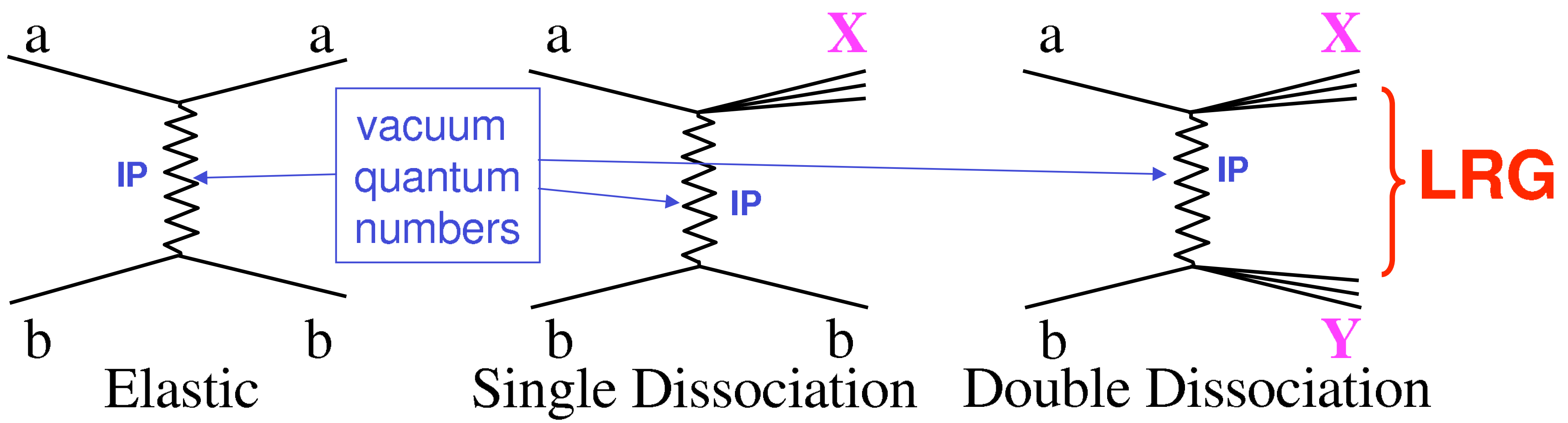


fig. courtesy by
Arneodo and Diehl

Diffraction in particle physics

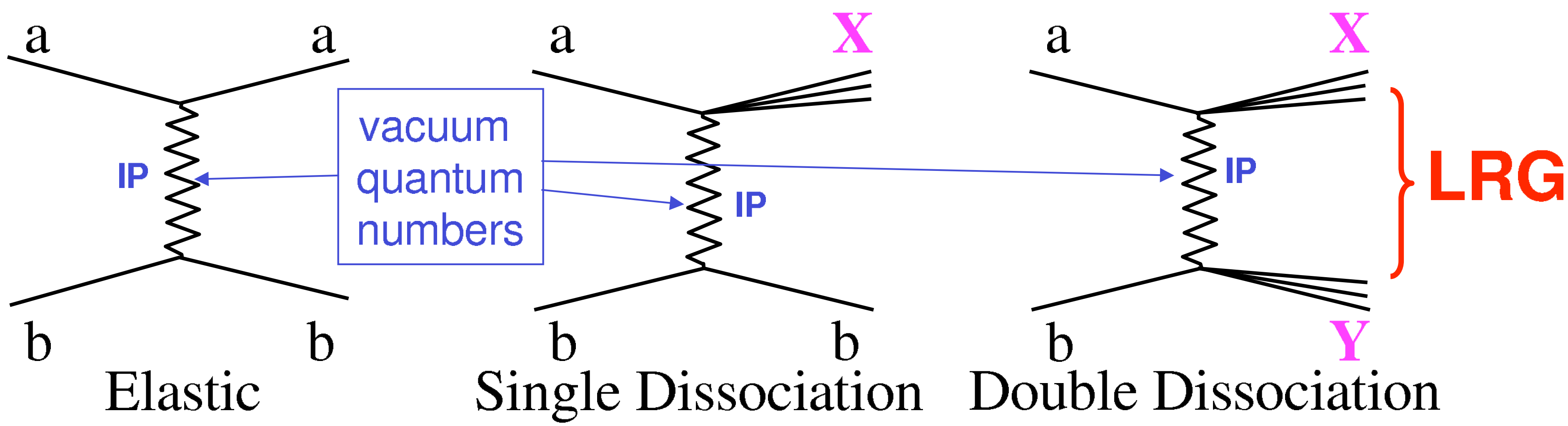


fig. courtesy by Arneodo and Diehl

Pomerantchuk theorem: in any process $a+b \rightarrow X$ t-channel state must have vacuum quantum numbers at s→∞.

Diffraction in particle physics

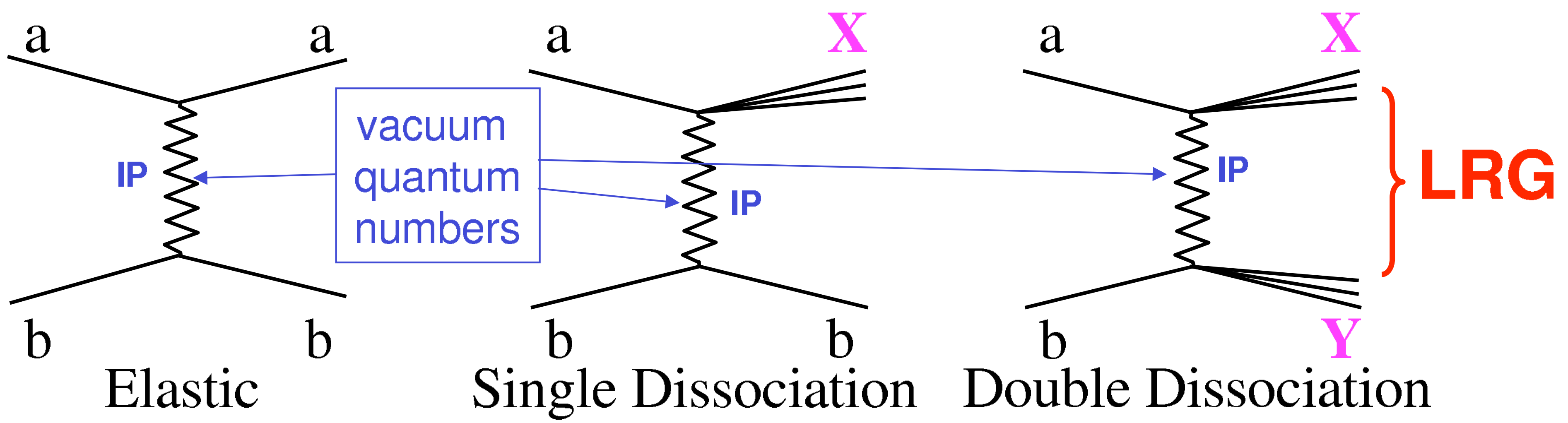
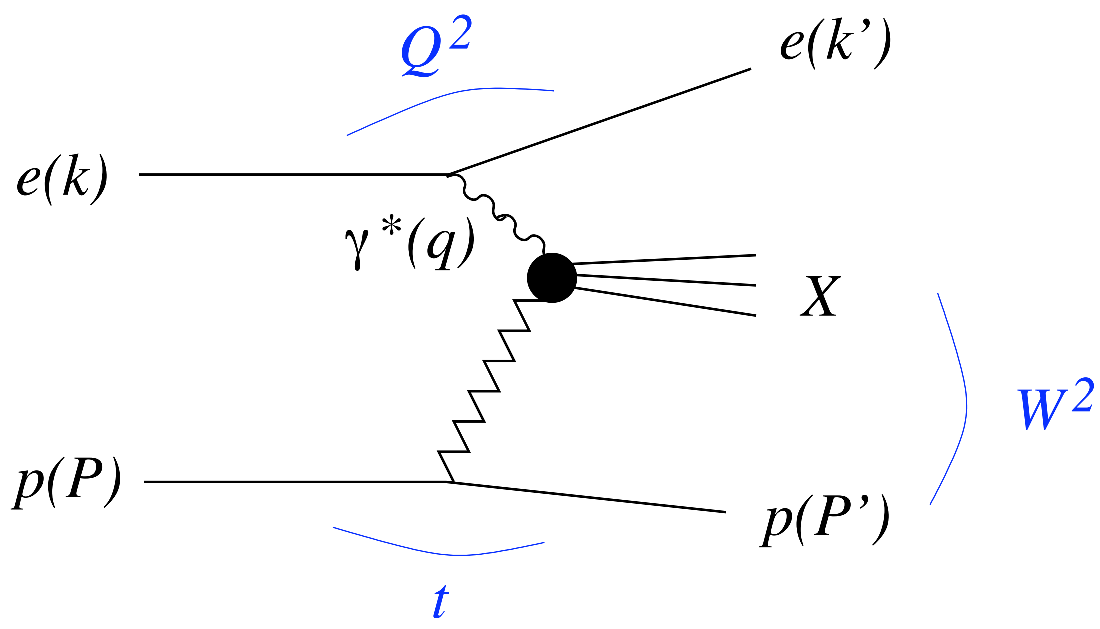


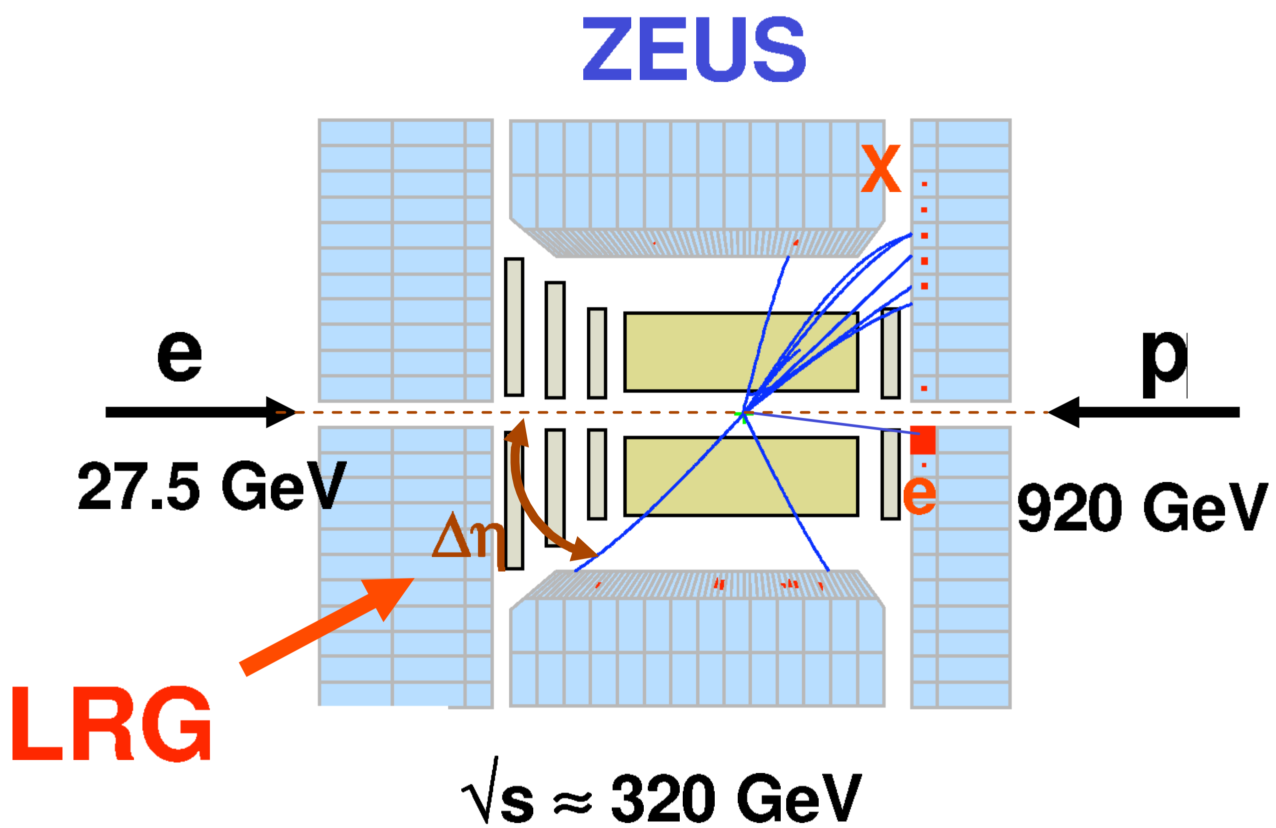
fig. courtesy by
Arneodo and Diehl

Pomerantchuk theorem: in any process $a+b \rightarrow X$ t-channel state must have vacuum quantum numbers at s→∞.

⇒ *Diffraction directly probes the high energy asymptotic.*

Diffraction at HERA

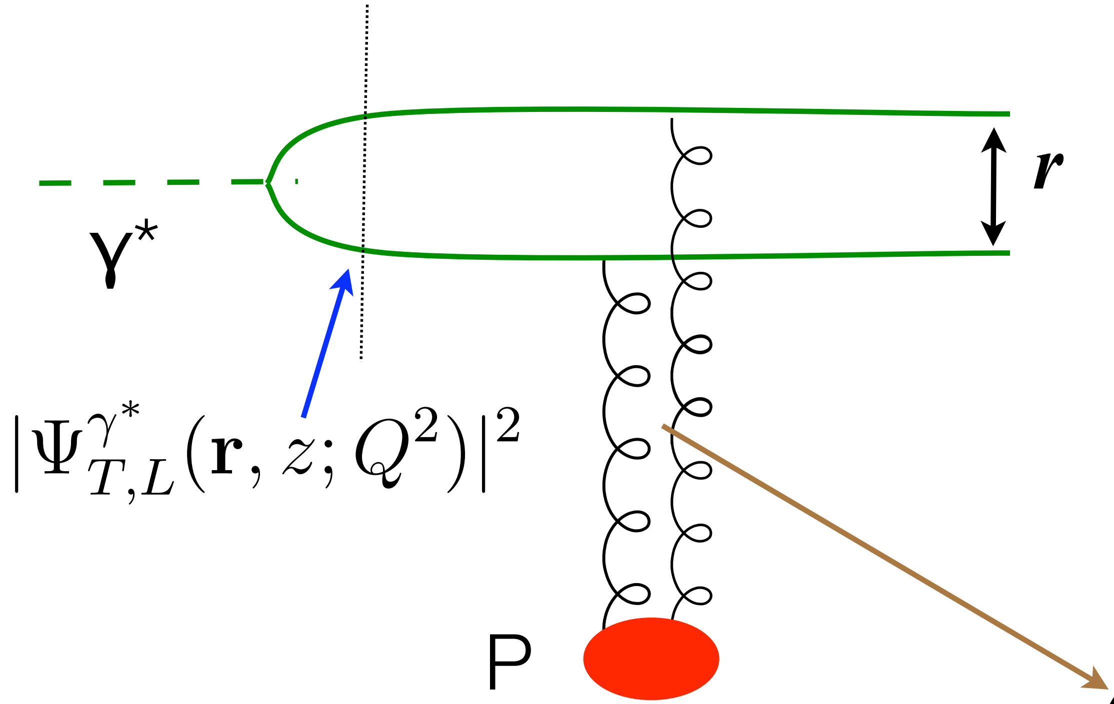




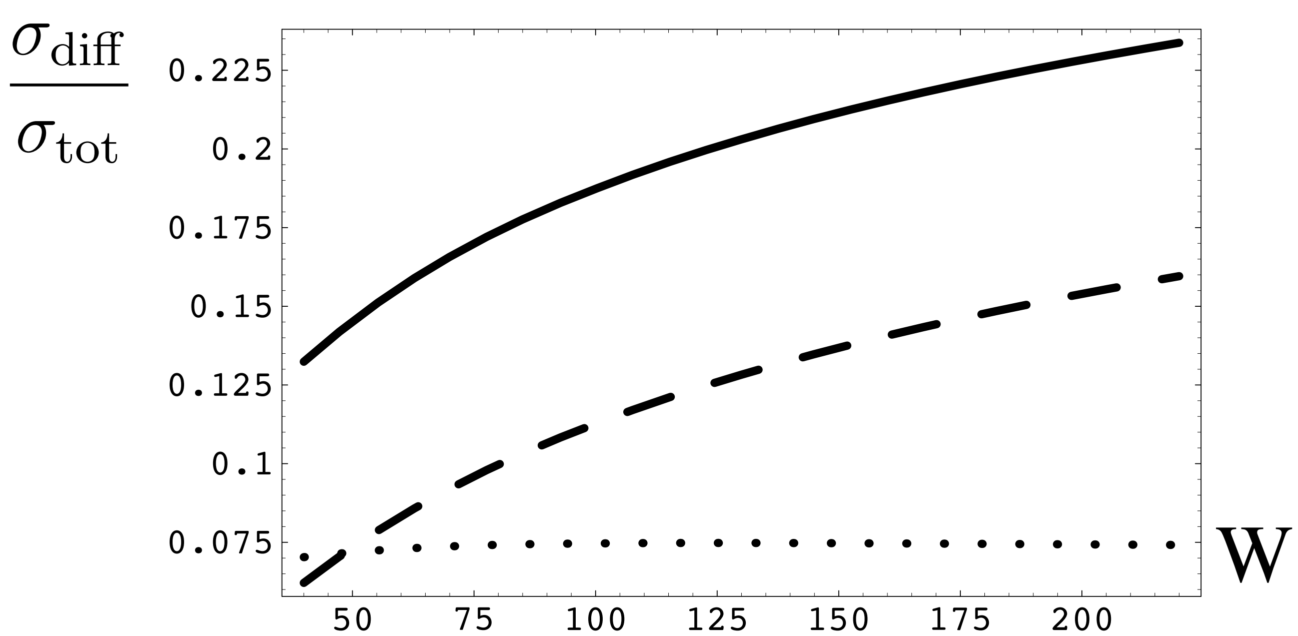
Unlike in pp, in DIS at $|t|>>\Lambda^2$ diffractive cross section can be calculated in pQCD

At low x $Q_s>>\Lambda$, so that even for small Q^2: $\alpha_s(Q_s)<<1$.

Kovchegov, McLerran, 99

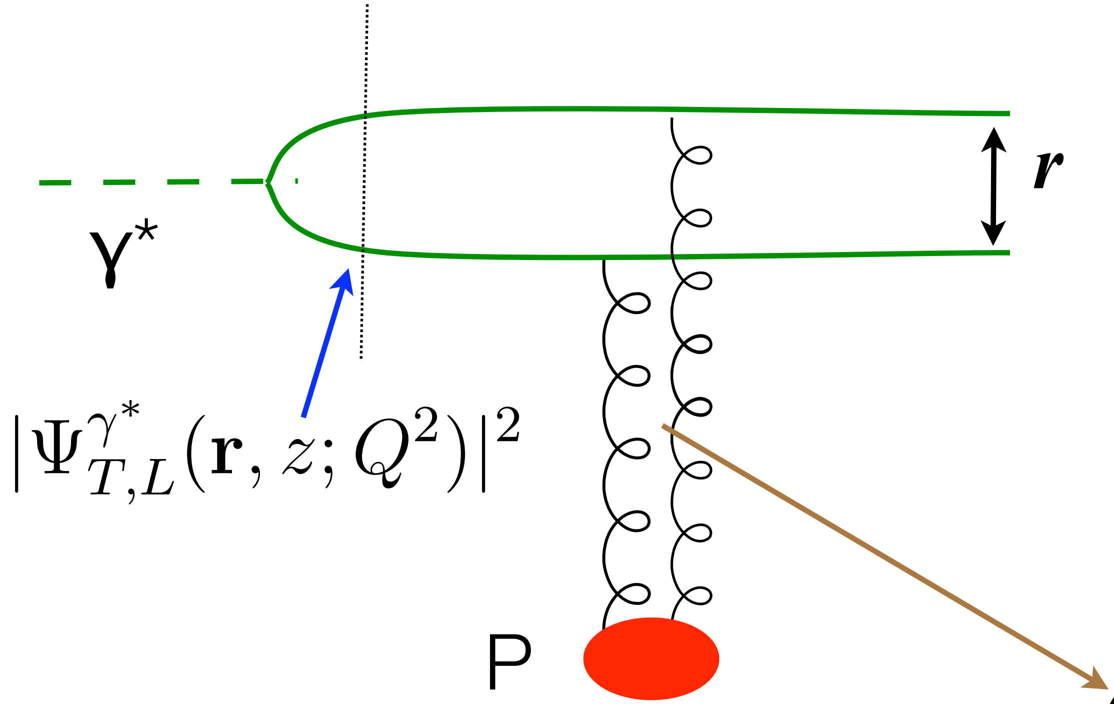


$$F_2^D = \frac{N_c R^2}{3\pi^2} \sum_f Z_f^2 \int d^2 r \int dz \, |\Psi^{\gamma^*}_{T,L}(\mathbf{r}, z; Q^2)|^2 \overbrace{\left(1 - e^{-\frac{1}{8}\mathbf{r}^2 Q_s^2 \ln \frac{1}{|\mathbf{r}|\mu}}\right)^2}$$



Gotsman at al.
99-01

Kovchegov, McLerran, 99



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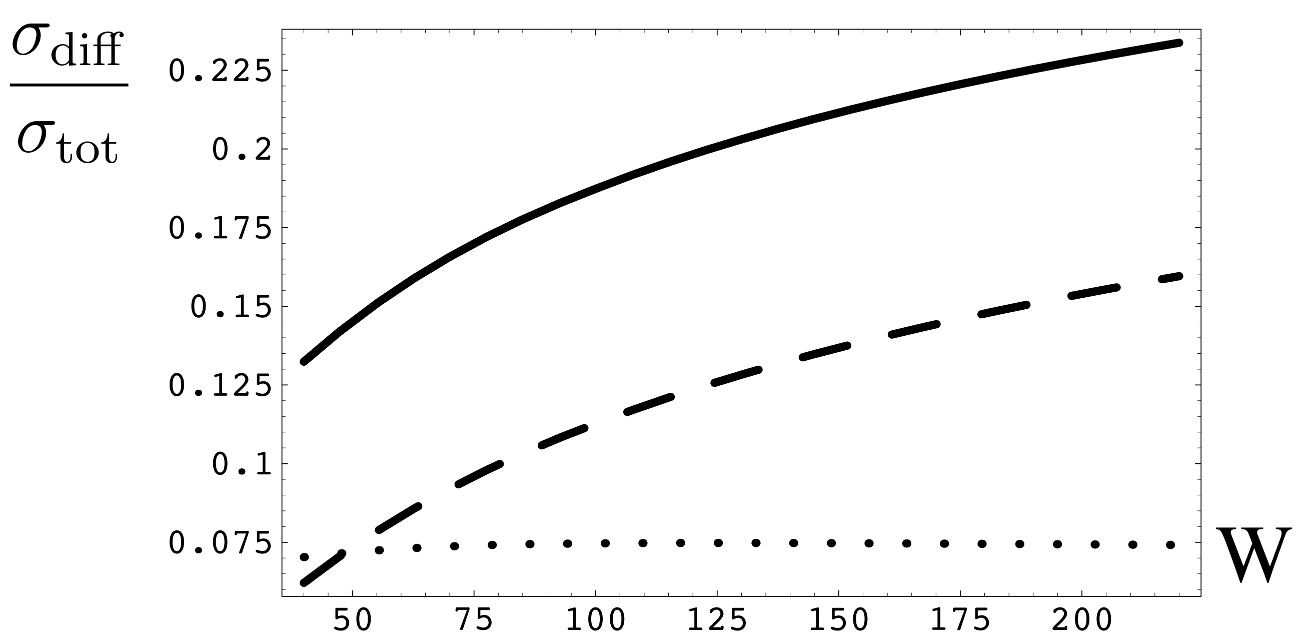

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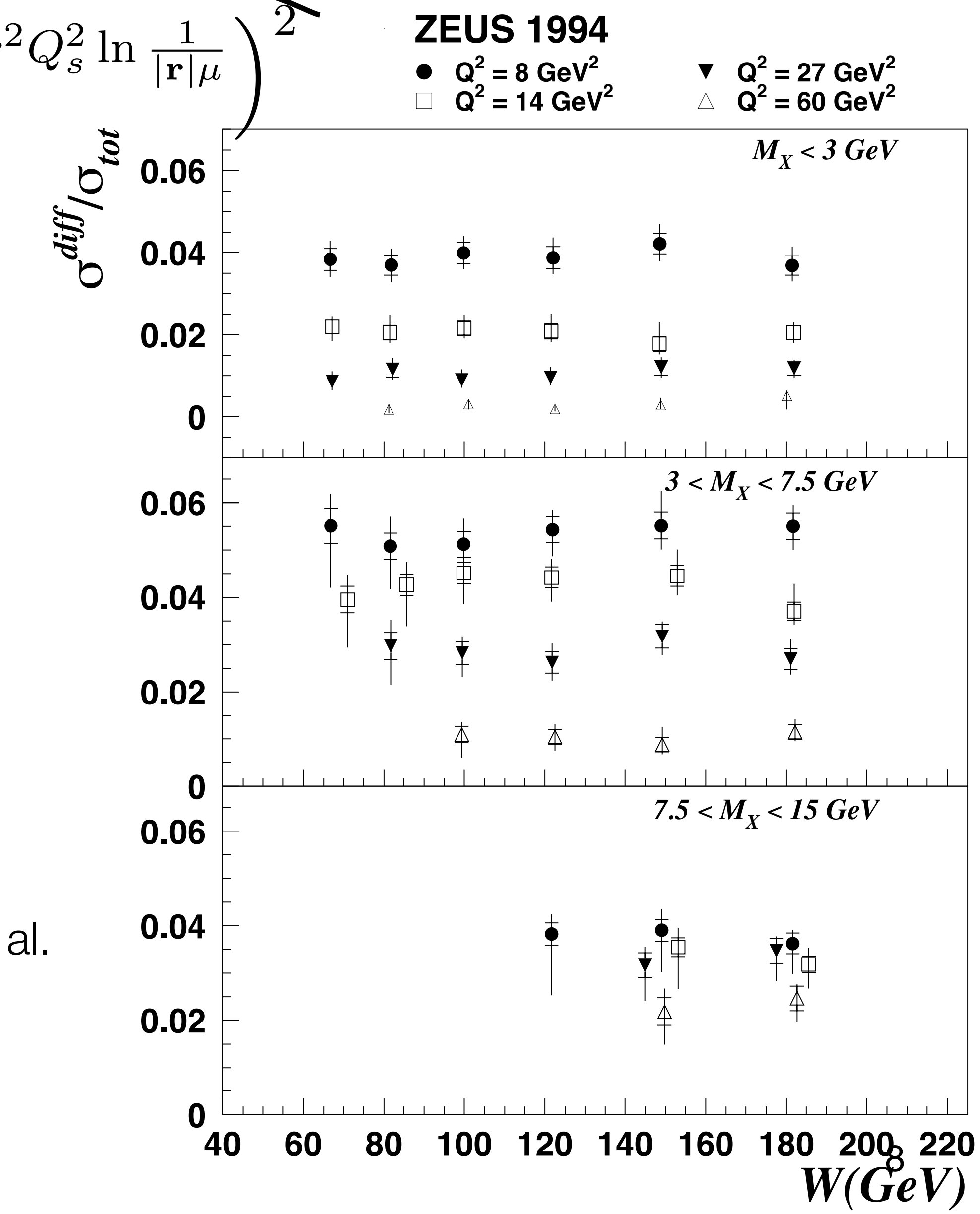
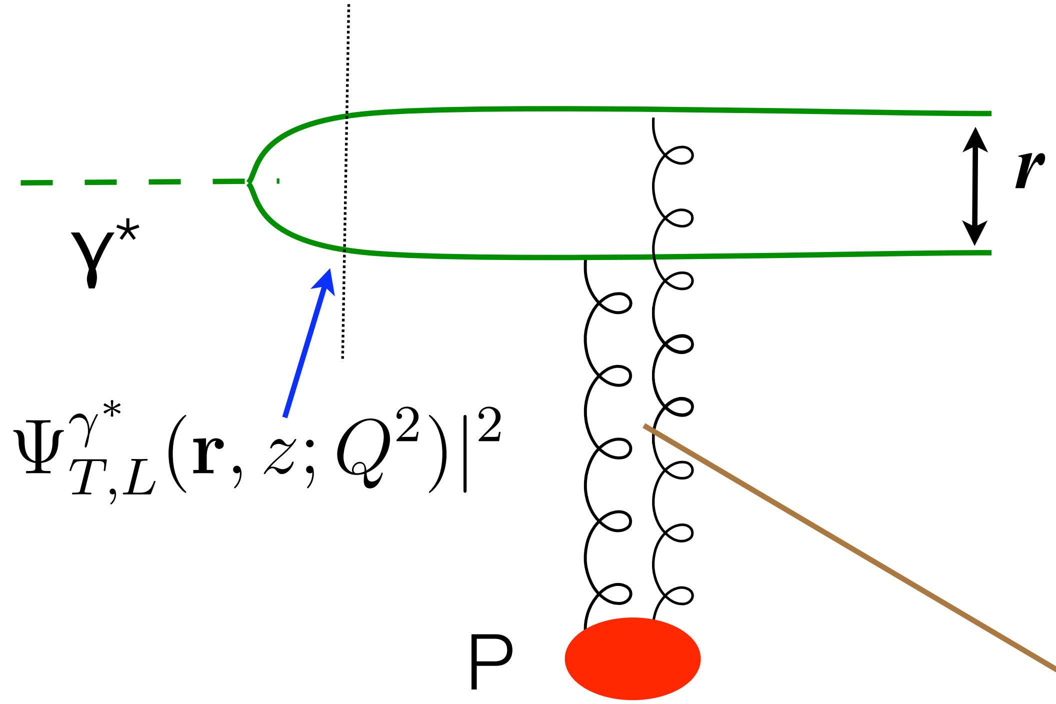
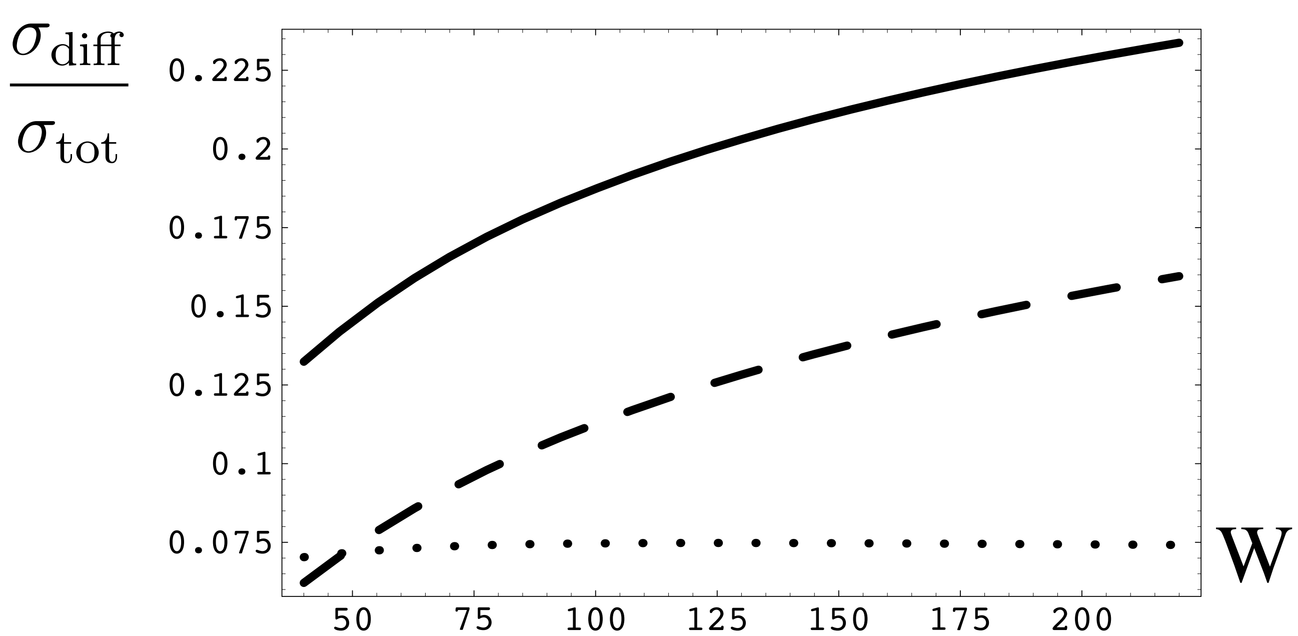




Kovchegov, McLerran, 99

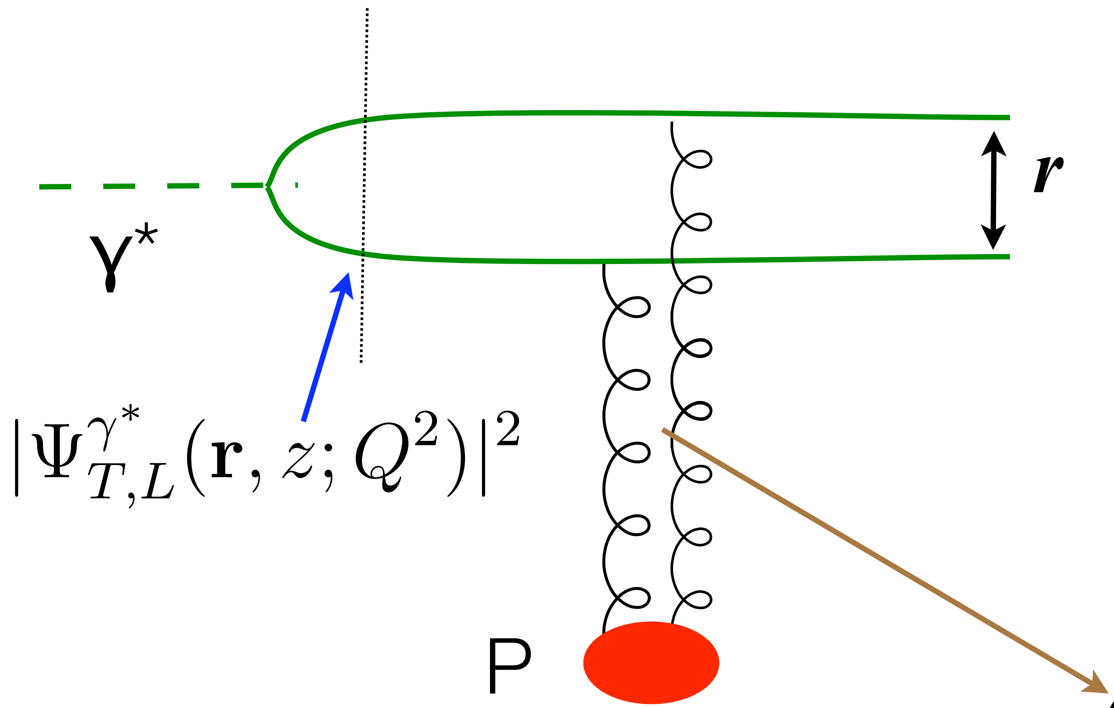
$$F_2^D = \frac{N_c R^2}{3\pi^2} \sum_f Z_f^2 \int d^2 r \int dz \, |\Psi_{T,L}^{\gamma^*}(\mathbf{r}, z; Q^2)|^2 \left(1 - e^{-\frac{1}{8}\mathbf{r}^2 Q_s^2 \ln \frac{1}{|\mathbf{r}|\mu}}\right)^2$$

This IR scale breaks the geometric scaling



Gotsman at al.
99-01

Kovchegov, McLerran, 99



$$F_2^D = \frac{N_c R^2}{3\pi^2} \sum_f Z_f^2 \int d^2r \int dz \, |\Psi^{\gamma^*}_{T,L}(\mathbf{r}, z; Q^2)|^2 \left(1 - e^{-\frac{1}{8}\mathbf{r}^2 Q_s^2 \ln \frac{1}{|\mathbf{r}|\mu}}\right)^2$$

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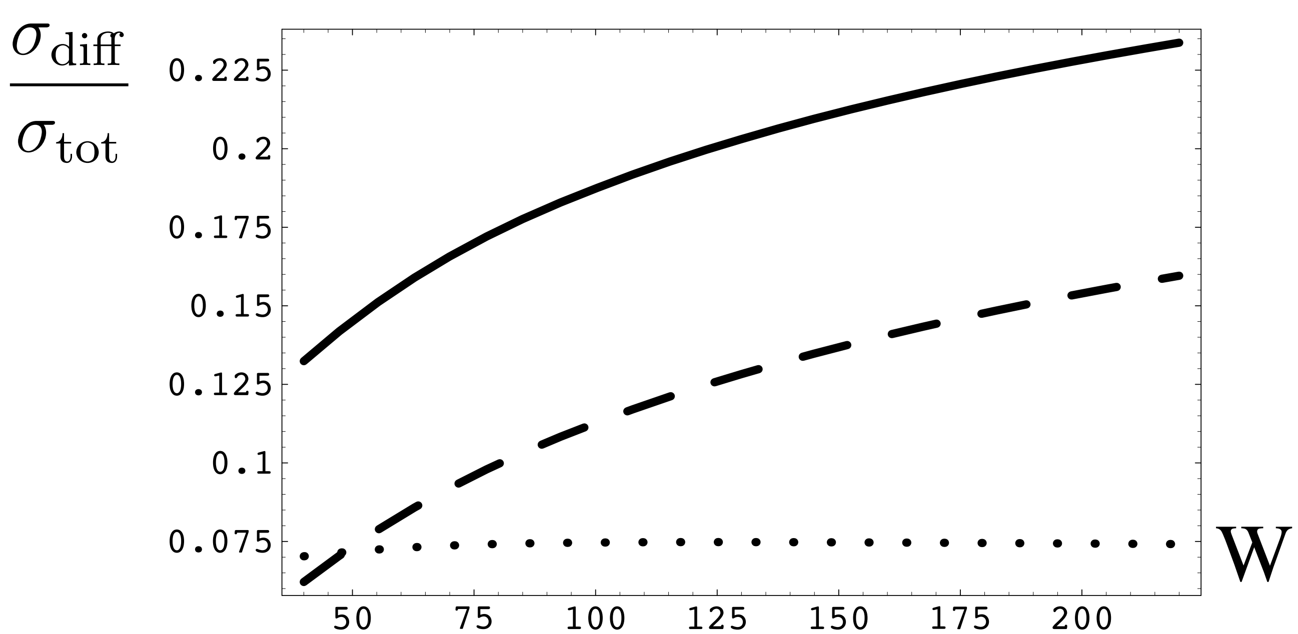
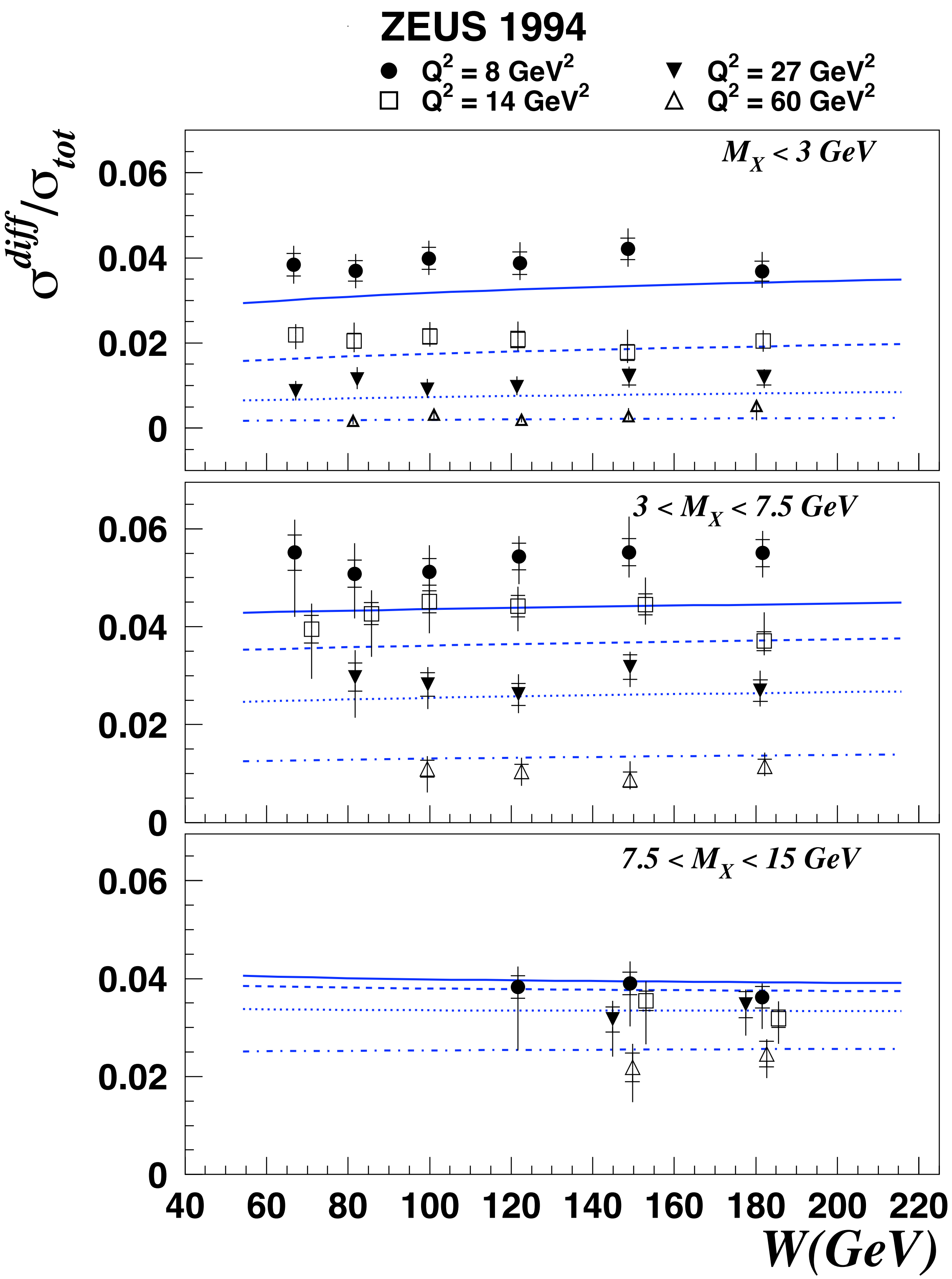


Gotsman at al. 99-01

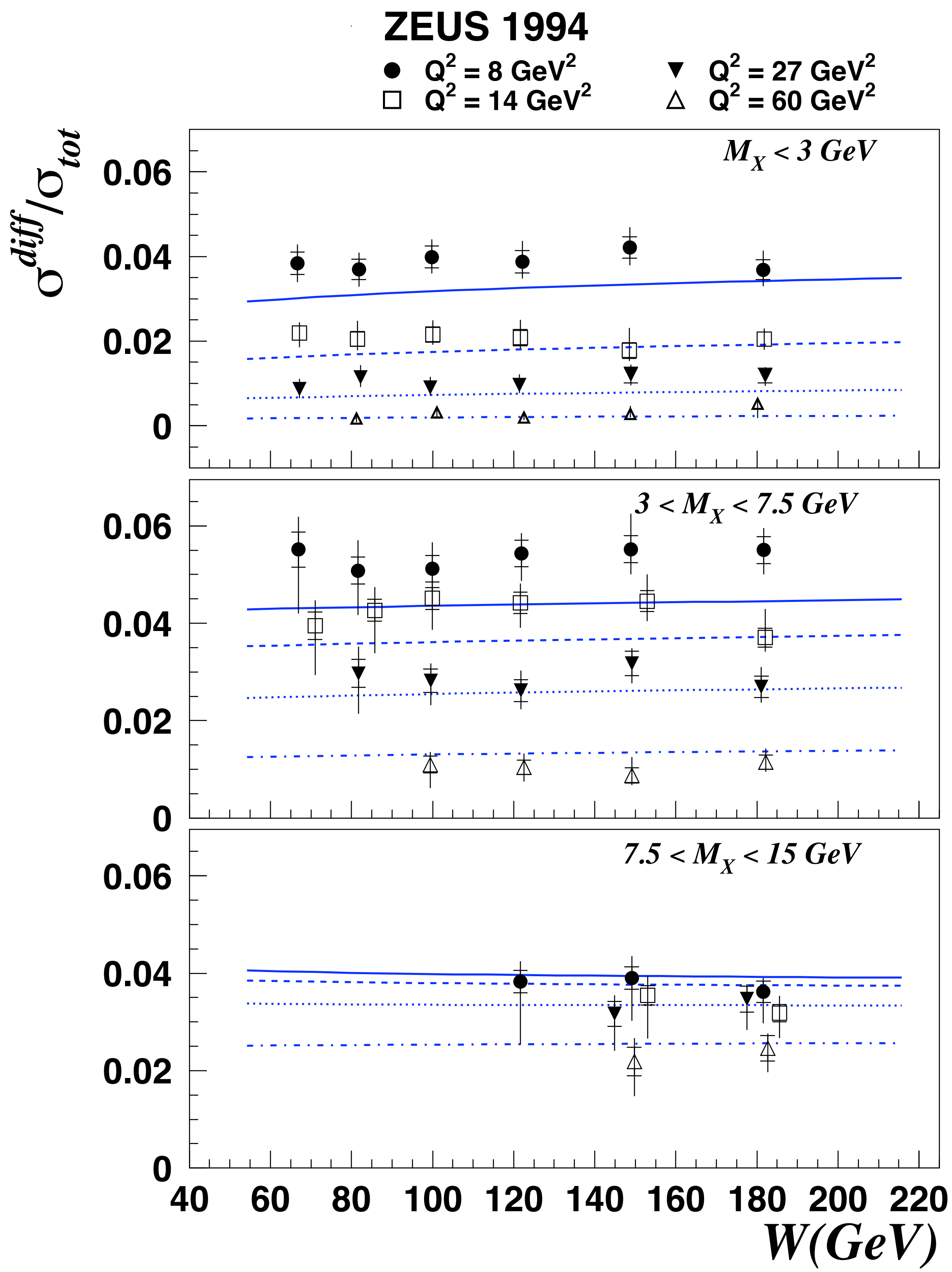
Low-x evolution removes dependence on the IR scale

Nonlinear evolution: Geometric Scaling

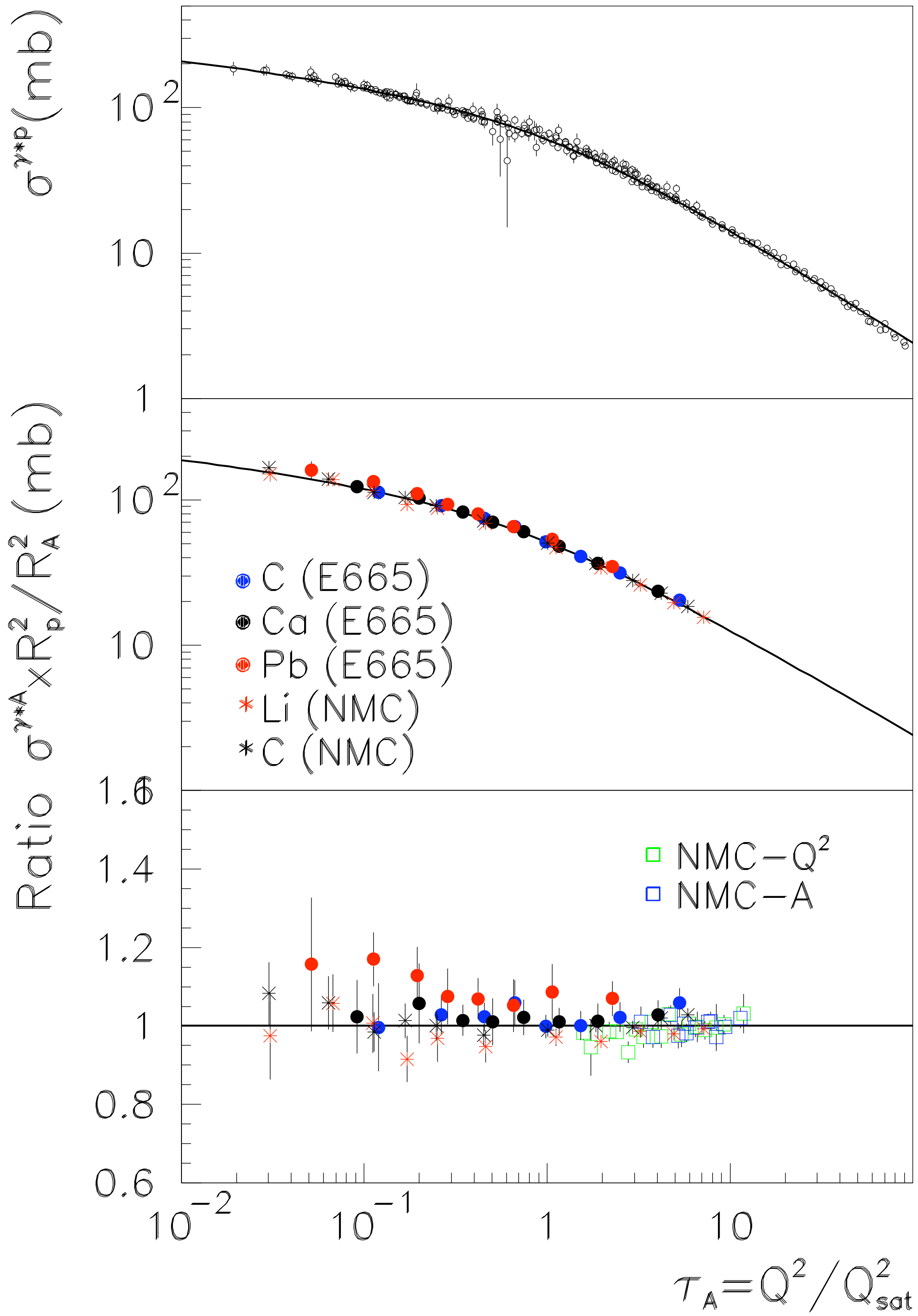


Golec-Biernat-Wusthoff, 99

Nonlinear evolution: Geometric Scaling



Golec-Biernat-Wusthoff, 99



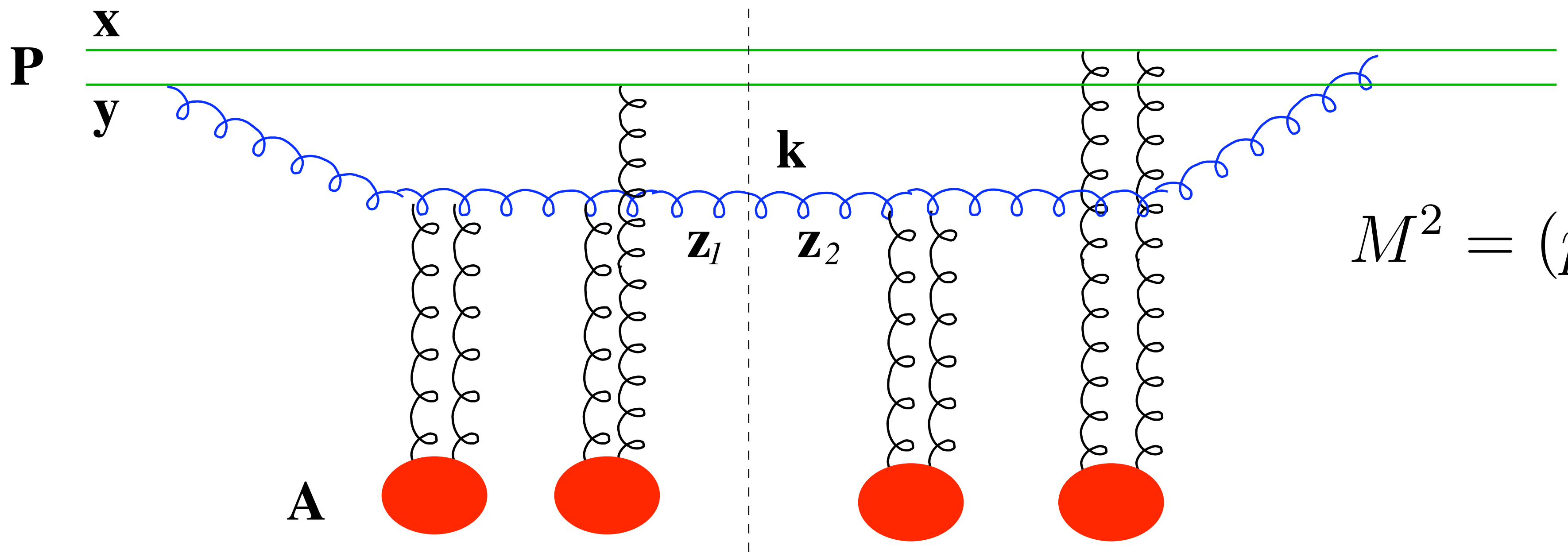
Stasto, Golec-Biernat, Kwiecinski, 00

Armesto, Salgado, Wiedemann, 04

Quasi-classical approximation

Kovchegov, 01
Kovner, Wiedemann, 01

Simple model: onium-nucleus collisions



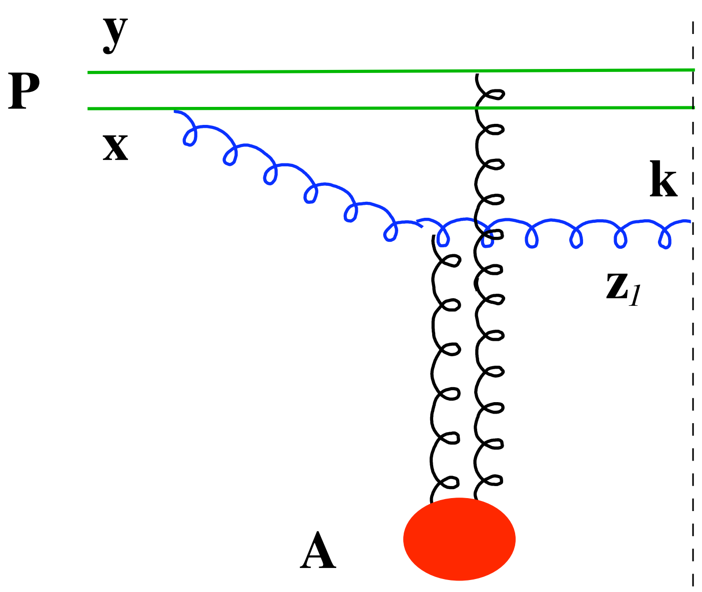
$$M^2 = (p+k)^2 = p_+ k_- = \frac{\mathbf{k}^2}{x}$$

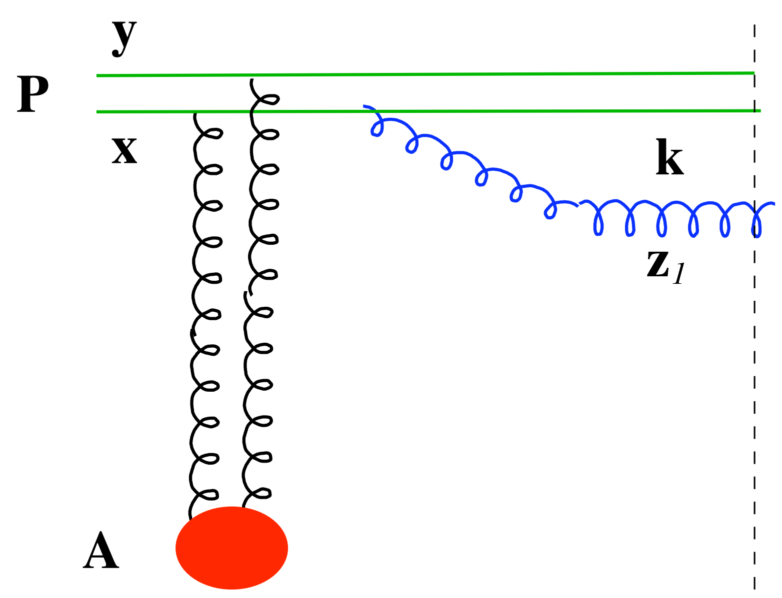
Coherent scattering if $l_c \approx \dfrac{1}{2m_N x} \gg R_A$

R_{Au} = 6.5 fm = 32 GeV^{-1}
x<<0.016

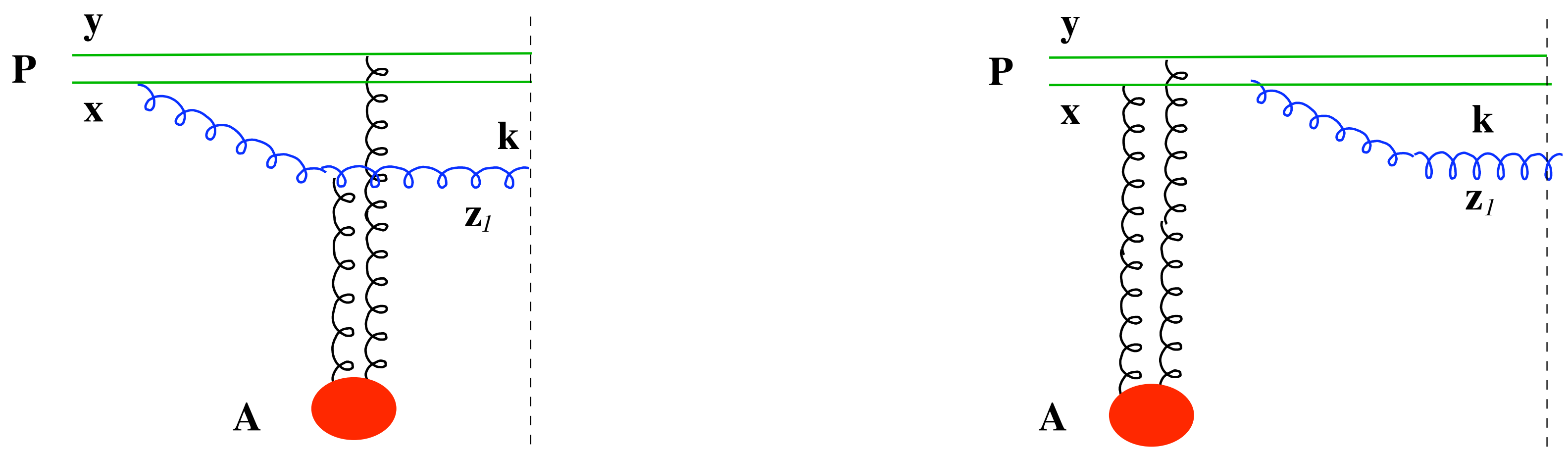
⇒ interaction is instantaneous

Two possible topologies:





All gluon attachments to the onium must be summed up.



qq propagator (Glauber-Mueller formula): $e^{-\frac{C_F}{4N_c}(\mathbf{x}-\mathbf{y})^2 Q_{s0}^2}$ Mueller, 90

qqg propagator: $\exp\{-P(\mathbf{x},\mathbf{y},\mathbf{z})\} = \exp\left(-\frac{1}{8}(\mathbf{x}-\mathbf{z})^2 Q_{s0}^2 - \frac{1}{8}(\mathbf{y}-\mathbf{z})^2 Q_{s0}^2 + \frac{1}{8N_c^2}(\mathbf{x}-\mathbf{y})^2 Q_{s0}^2\right)$.

Kopeliovich, Tarasov, Schafer,99

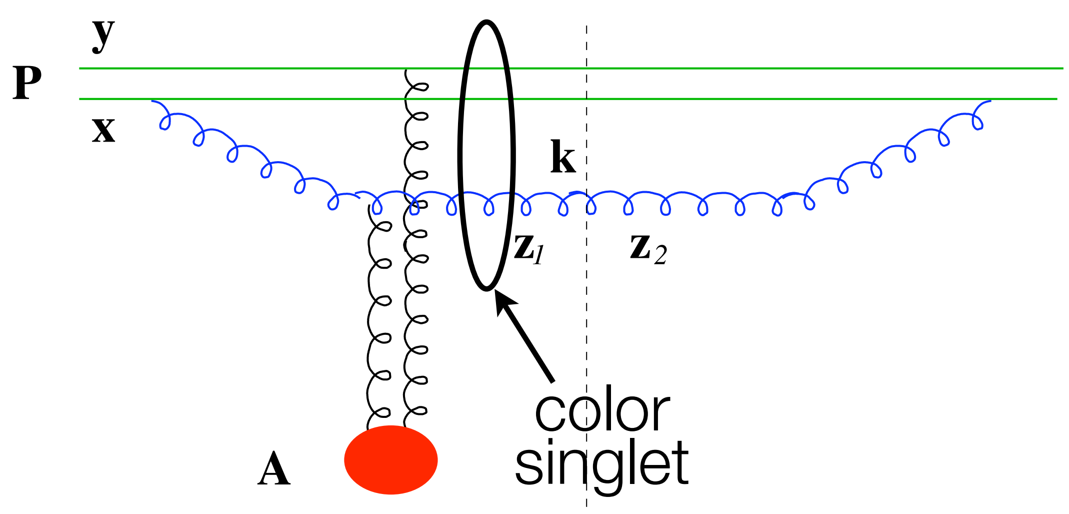
‘initial’ *gluon* saturation scale $Q_{s0}^2 = \frac{4\pi^2 \alpha_s N_c}{N_c^2-1}\,\rho\, T(\mathbf{b})\, xG(x, 1/\mathbf{r}^2)$

$$\frac{d\sigma(k,y)}{d^2k\,dy} = \frac{\alpha_s C_F}{\pi^2}\frac{1}{(2\pi)^2}\int d^2b\, d^2z_1\, d^2z_2 \left(\frac{\mathbf{z}_1-\mathbf{x}}{|\mathbf{z}_1-\mathbf{x}|^2} - \frac{\mathbf{z}_1-\mathbf{y}}{|\mathbf{z}_1-\mathbf{y}|^2}\right)\cdot\left(\frac{\mathbf{z}_2-\mathbf{x}}{|\mathbf{z}_2-\mathbf{x}|^2} - \frac{\mathbf{z}_2-\mathbf{y}}{|\mathbf{z}_2-\mathbf{y}|^2}\right)$$

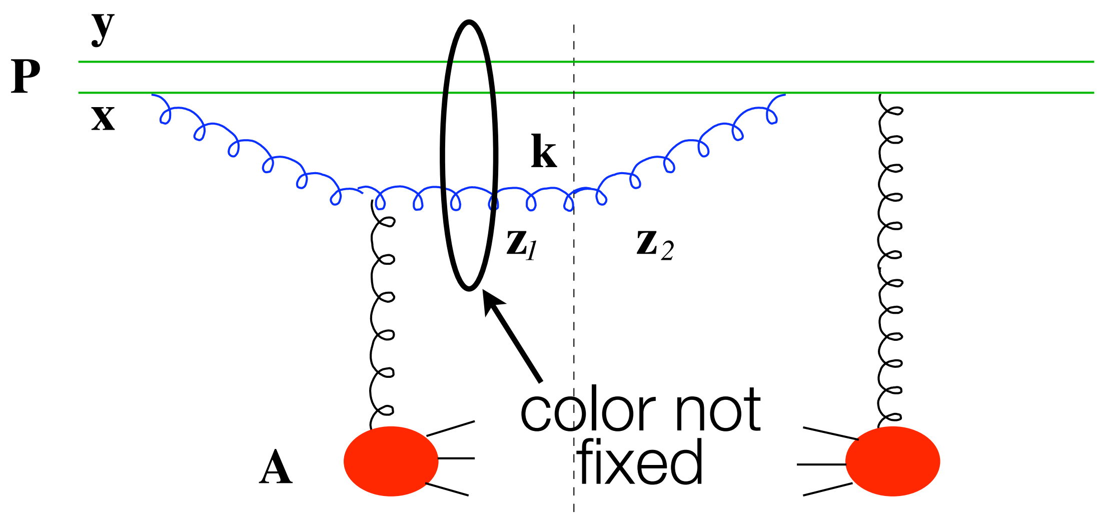
$$\times\, e^{-i\mathbf{k}\cdot(\mathbf{z}_1-\mathbf{z}_2)}\left(e^{-P(\mathbf{x},\mathbf{y},\mathbf{z}_1)} - e^{-\frac{C_F}{4N_c}(\mathbf{x}-\mathbf{y})^2 Q_{s0}^2}\right)\left(e^{-P(\mathbf{x},\mathbf{y},\mathbf{z}_2)} - e^{-\frac{C_F}{4N_c}(\mathbf{x}-\mathbf{y})^2 Q_{s0}^2}\right)$$

If log is dropped these integrals can be done.

Diffractive vs Inclusive gluon production



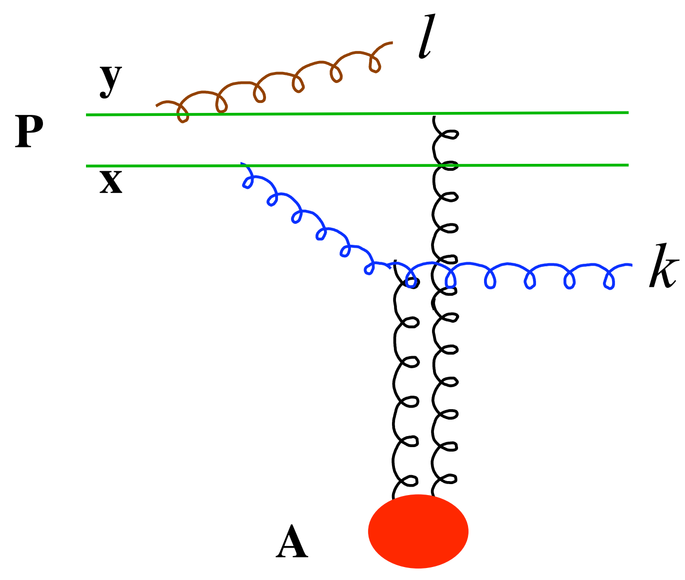
$$\exp\left(-\frac{1}{8}(\mathbf{x}-\mathbf{z})^2 Q_{s0}^2 - \frac{1}{8}(\mathbf{y}-\mathbf{z})^2 Q_{s0}^2 + \frac{1}{8N_c^2}(\mathbf{x}-\mathbf{y})^2 Q_{s0}^2\right)$$



$$\frac{g\left(\mathbf{x}-\mathbf{z}_1\right)}{\left|\mathbf{x}-\mathbf{z}_1\right|^2}\, e^{-\frac{1}{4}(\mathbf{x}-\mathbf{z}_1)^2 Q_{s0}^2}$$

Unlike the inclusive gluon production, the diffractive one vanishes when the onium size **r**=**x-y** larger than 1/Qs.

Including small-x corrections

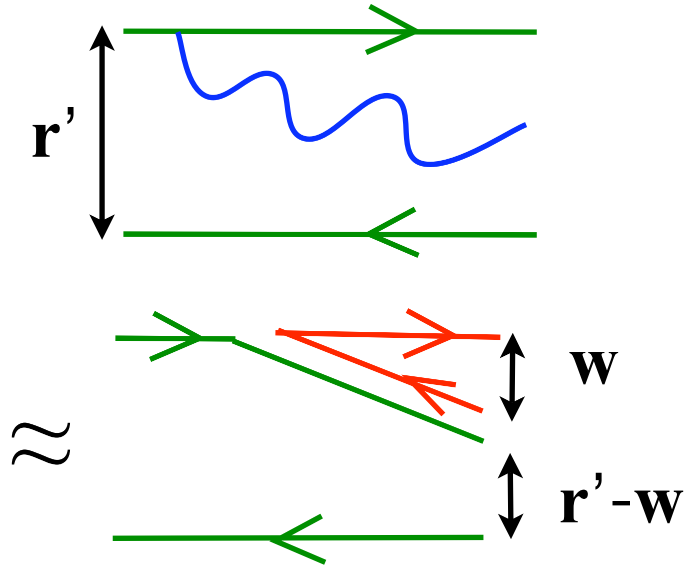


There are <u>two cases</u>:

(1) Fast gluons $l_{+} >> k_{+}$ and

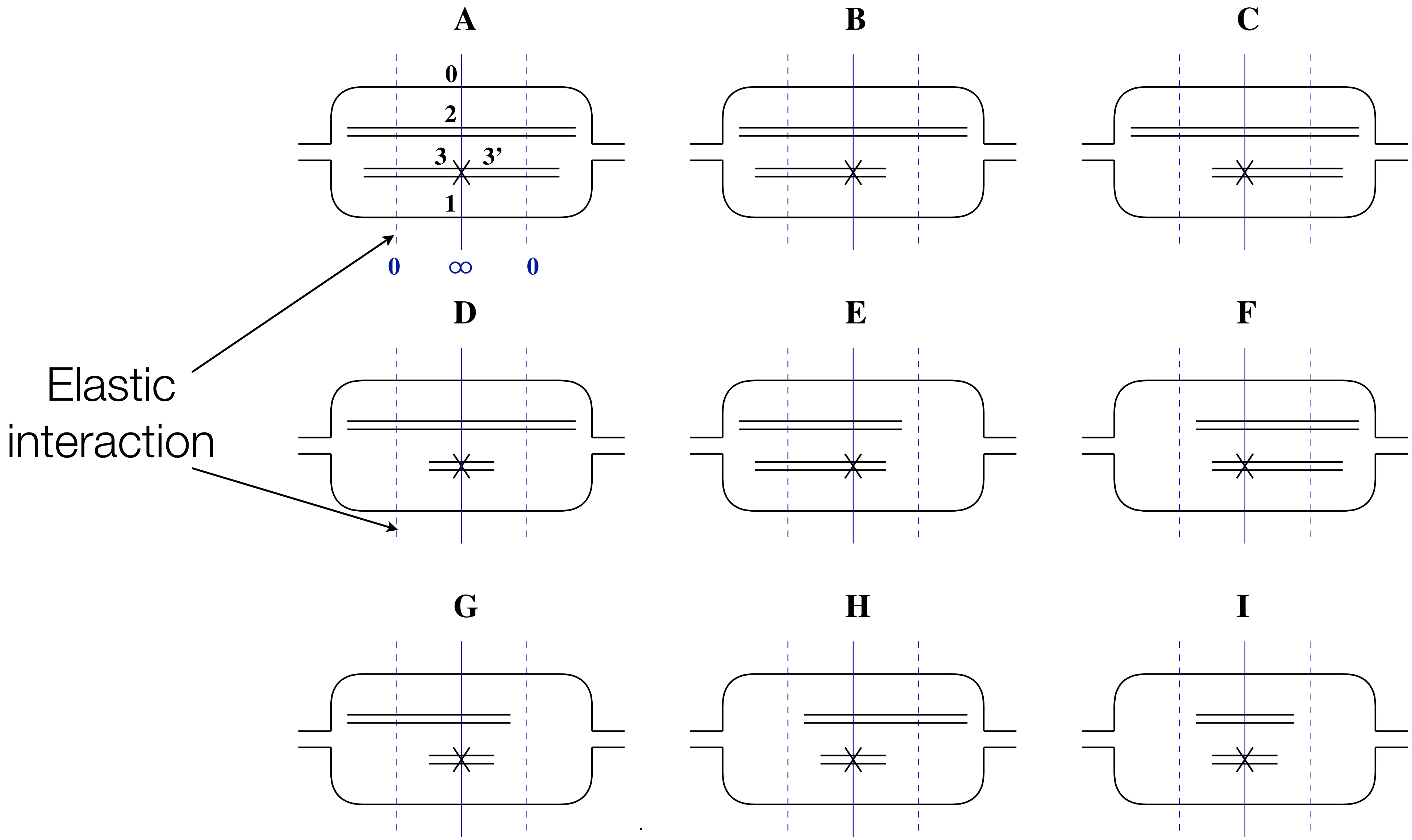
(2) Slow gluons $k_{+} >> l_{+}$

Large N_c:



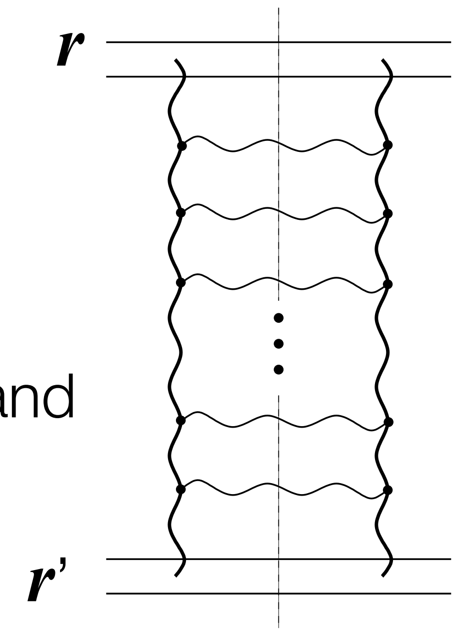
Fast gluons $l_+ >> k_+$

Only diagrams contributing in the LLA are shown



All fast gluons can be resumed into gluon dipole density $n(\mathbf{r},\mathbf{r}',\mathbf{b},y)$

This corresponds to the Pomeron hanging out from the incoming dipole $\boldsymbol{r}$ and connecting with the emitting dipole $\boldsymbol{r}'$



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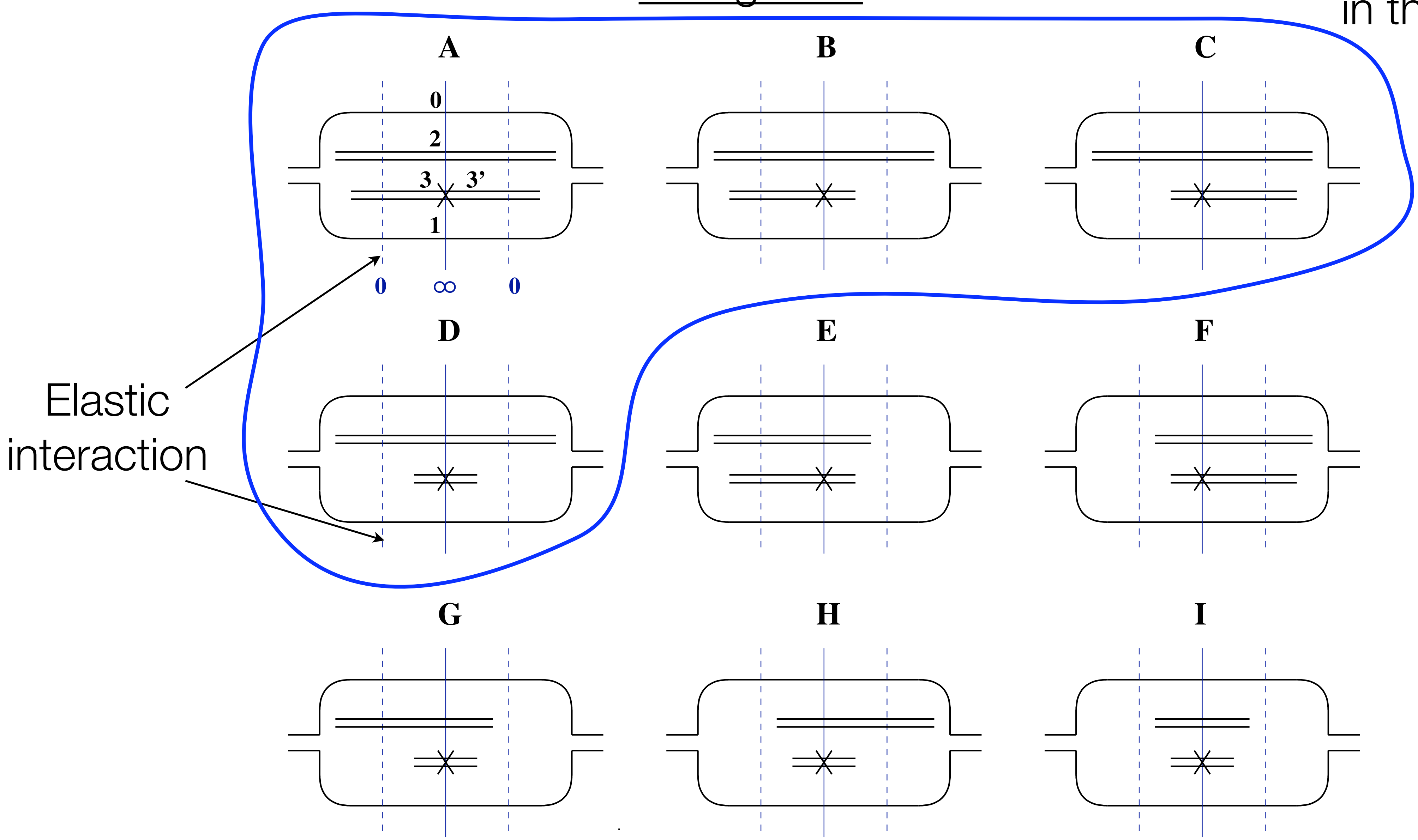
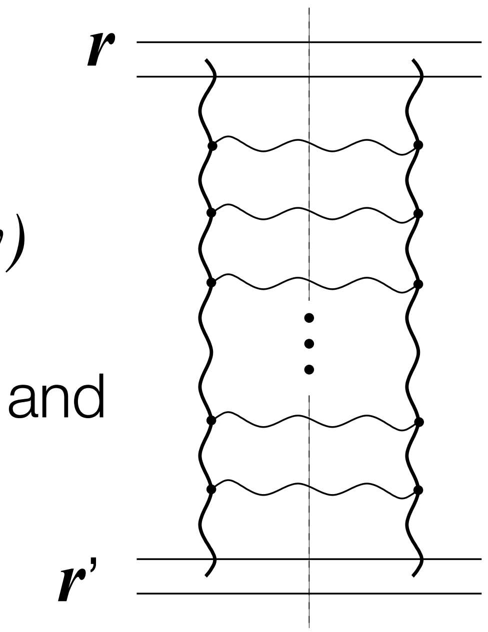
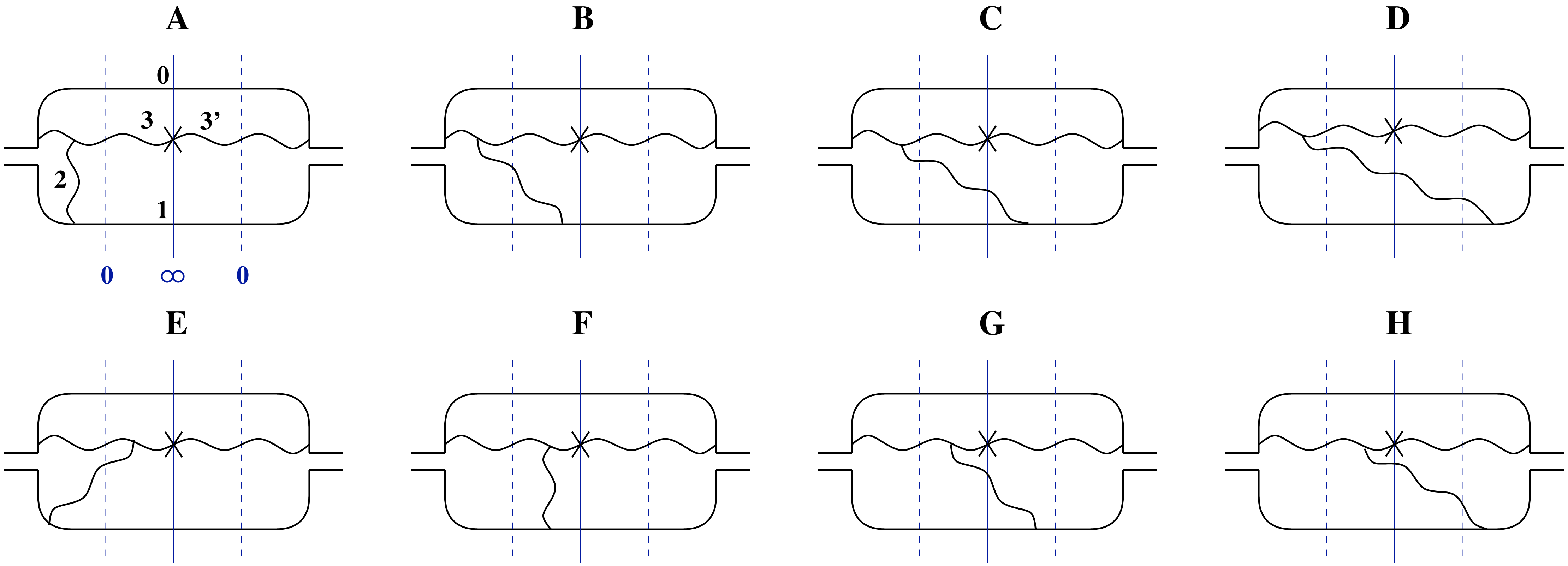




All fast gluons can be resumed into gluon dipole density $n(\mathbf{r},\mathbf{r}',\mathbf{b},y)$

This corresponds to the Pomeron hanging out from the incoming dipole $\boldsymbol{r}$ and connecting with the emitting dipole $\boldsymbol{r}'$

Slow gluons $k_+ >> l_+$

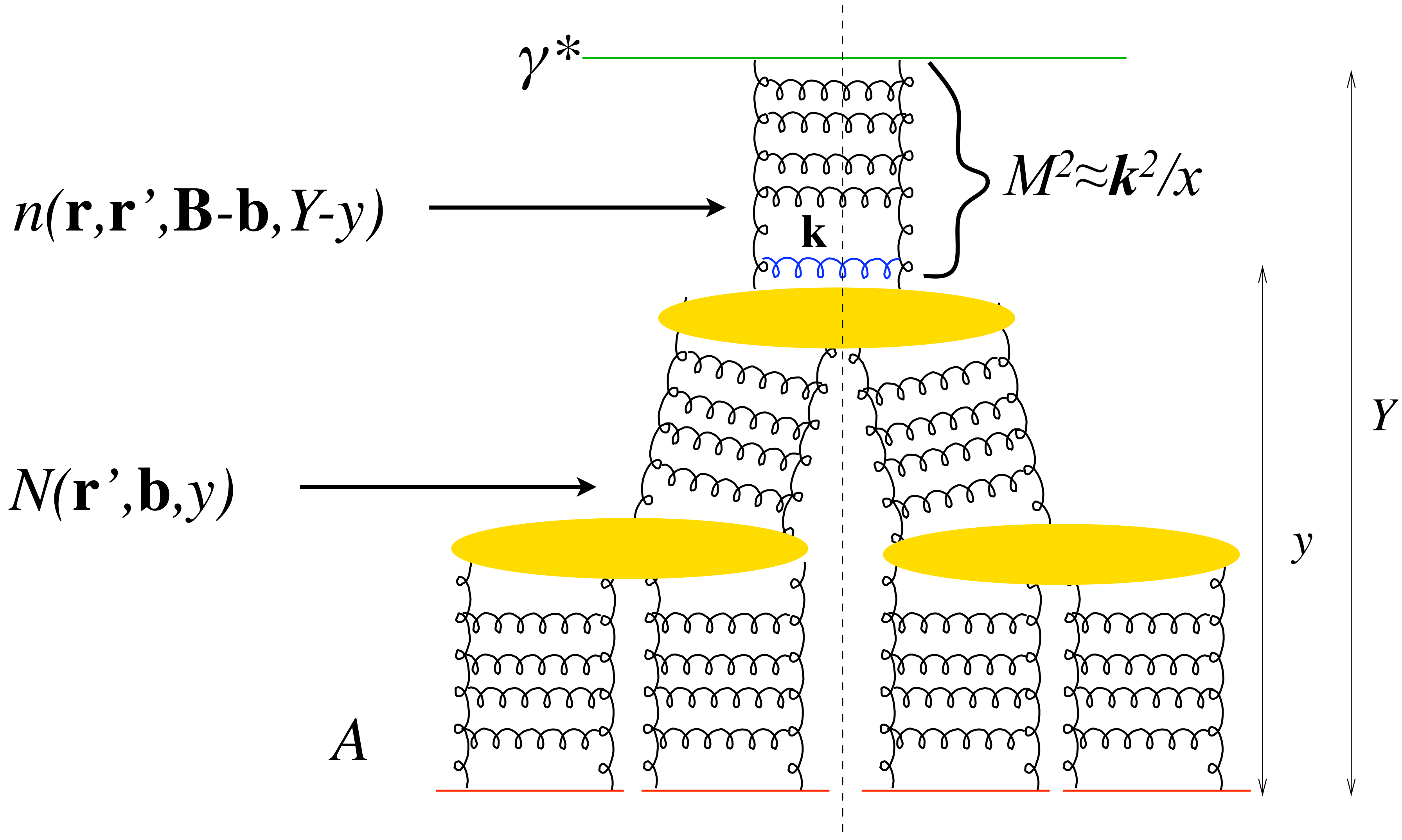


All slow gluons can be resumed into the forward elastic gluon dipole $\mathbf{r}'$ scattering amplitude $N(\mathbf{r}',\mathbf{b},y)$

if

the measured gluon is adjacent to the rapidity gap

(this is the most interesting case for phenomenology: $M^2=k^2/x$)



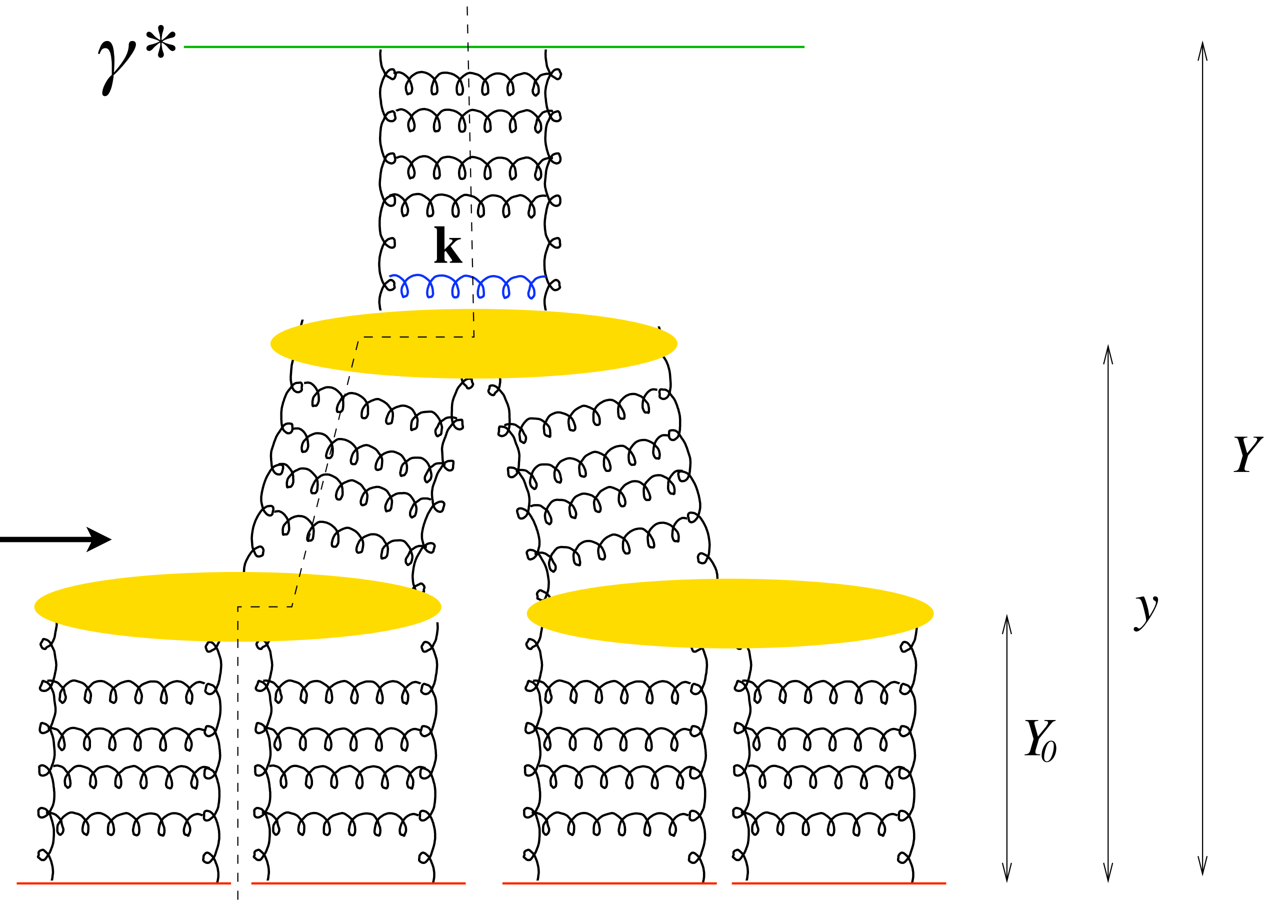
$N(\mathbf{r}',\mathbf{b},y)$ satisfies the BK equation

$$\frac{\partial N(\mathbf{x}-\mathbf{y},\mathbf{b},y)}{\partial y} = \frac{\alpha_s N_c}{2\pi^2}\int d^2z\,\frac{(\mathbf{x}-\mathbf{y})^2}{(\mathbf{x}-\mathbf{z})^2(\mathbf{y}-\mathbf{z})^2}\big[N(\mathbf{x}-\mathbf{z},\mathbf{b},y) + N(\mathbf{y}-\mathbf{z},\mathbf{b},y) - N(\mathbf{x}-\mathbf{y},\mathbf{b},y) - N(\mathbf{x}-\mathbf{z},\mathbf{b},y)N(\mathbf{y}-\mathbf{z},\mathbf{b},y)\big]$$

with the initial condition $N_A(\mathbf{r},\mathbf{b},0) = 1 - e^{-\frac{1}{8}\mathbf{r}^2\,Q_{s0}^2}$

$n(\mathbf{r},\mathbf{r}',\mathbf{B}-\mathbf{b},Y-y)$ satisfies the BFKL equation (in accordance with the AGK cutting rules) with the initial condition

$$n(\mathbf{r},\mathbf{r}',\mathbf{b},0) = \delta(\mathbf{r}-\mathbf{r}')\,\delta(\mathbf{b})$$



A more general case:

(this is true only for the total inclusive)

$N_D(\mathbf{r},\mathbf{b},y;Y_0)$ →

$N_D(\mathbf{r},\mathbf{b},y;Y_0)$ satisfies the *Kovchegov-Levin equation*

$$\frac{\partial N_D(\mathbf{x}-\mathbf{y},\mathbf{b},y;Y_0)}{\partial y} = \frac{2\alpha_s C_F}{\pi^2}\int d^2z\left[\frac{(\mathbf{x}-\mathbf{y})^2}{(\mathbf{x}-\mathbf{z})^2(\mathbf{y}-\mathbf{z})^2} - 2\pi\delta(\mathbf{y}-\mathbf{z})\ln(|\mathbf{x}-\mathbf{y}|\Lambda)\right]N_D(\mathbf{x}-\mathbf{z},\mathbf{b},y;Y_0)$$

$$+\frac{\alpha_s C_F}{\pi^2}\int d^2z\frac{(\mathbf{x}-\mathbf{y})^2}{(\mathbf{x}-\mathbf{z})^2(\mathbf{y}-\mathbf{z})^2}\left[N_D(\mathbf{x}-\mathbf{z},\mathbf{b},y;Y_0)N_D(\mathbf{y}-\mathbf{z},\mathbf{b},y;Y_0)\right.$$

$$\left.4N_D(\mathbf{x}-\mathbf{z},\mathbf{b},y;Y_0)N(\mathbf{y}-\mathbf{z},\mathbf{b},y) + 2N(\mathbf{x}-\mathbf{z},\mathbf{b},y)N(\mathbf{y}-\mathbf{z},\mathbf{b},y)\right]$$

with the initial condition $N_D(\mathbf{r},\mathbf{b},y=Y_0;Y_0) = N^2(\mathbf{r},\mathbf{b},Y_0)$

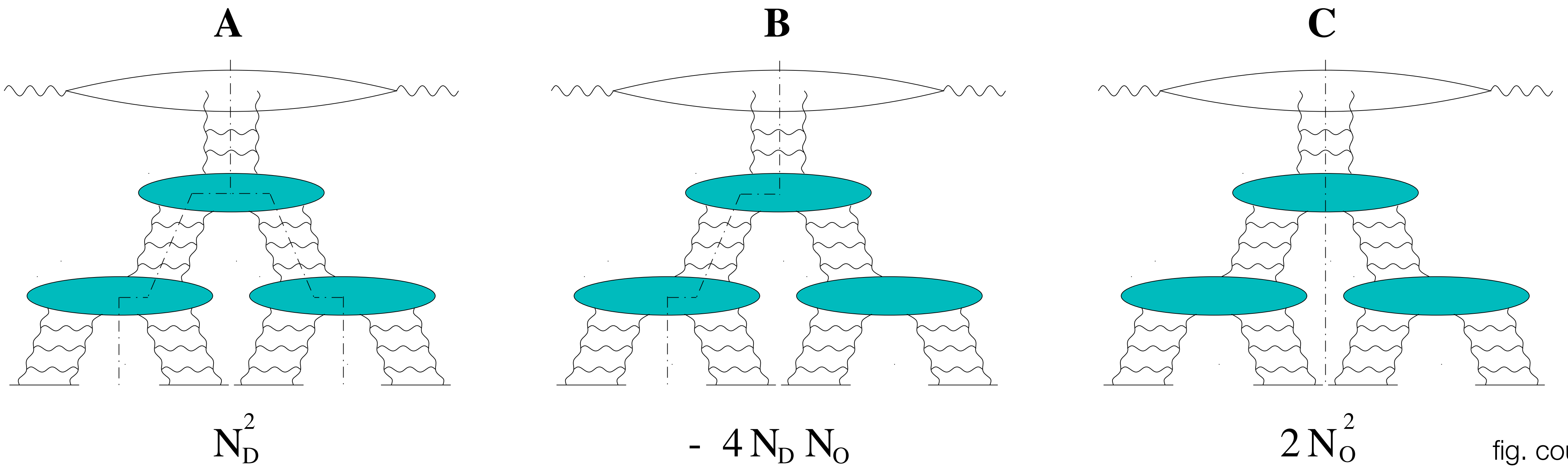


fig. courtesy by Kovchegov and Levin

Various terms in the Kovchegov-Levin equation comply with the AGK cutting rules

A) (cut Pomeron 2) × (symmetry factor 1/2) = 1

B) (cut Pomeron 2) × (number of diagrams 2) = 4

C) (cut Pomeron 2) = 2

$$2\mathrm{Im}\, a_{el}^{BFKL} = G_{in}^{BFKL}$$

one Pomeron (in forward amplitude) → a_{el}^{BFKL}

Total inelastic c.s. → G_{in}^{BFKL}

Effect of evolution in the onium

$$\frac{d\sigma(k,y)}{d^2k\,dy} = \frac{\alpha_s C_F}{\pi^2}\frac{1}{(2\pi)^2} S_A \int d^2r'\, n_p(\mathbf{r},\mathbf{r}',Y-y)\,|\mathbf{I}(\mathbf{r}',\mathbf{k},y)|^2$$

we assume cylindrical nuclei

original dipole → $\mathbf{r}$; intermediate dipole → $\mathbf{r}'$

where $\mathbf{I}(\mathbf{r}',\mathbf{k},y) = -e^{-i\mathbf{k}\cdot\mathbf{r}'}\, i\nabla_{\mathbf{k}} Q(\mathbf{r}',\mathbf{k},y) + i\nabla_{\mathbf{k}} Q^*(\mathbf{r}',\mathbf{k},y)$

$$Q(\mathbf{r}',\mathbf{k},y) = -\int d^2w\, e^{i\mathbf{k}\cdot\mathbf{w}}\frac{1}{w^2}\,[N(\mathbf{r}',\mathbf{b},y) - N(\mathbf{w}-\mathbf{r}',\mathbf{b},y) - N(\mathbf{w},\mathbf{b},y) + N(\mathbf{w}-\mathbf{r}',\mathbf{b},y)N(\mathbf{w},\mathbf{b},y)]$$

As rapidity interval Y-y between the onium and the gluon increases, the dipole density evolves with BFKL:

$$n_p(\mathbf{r},\mathbf{r}',y) = \frac{1}{2\pi^2 r'^2}\int_{-\infty}^{\infty} d\nu\, e^{2\bar{\alpha}_s\chi(\nu)y}\,(r/r')^{1+2i\nu} \qquad n_p(\mathbf{r},\mathbf{r}',0) = \delta(\mathbf{r}-\mathbf{r}')$$

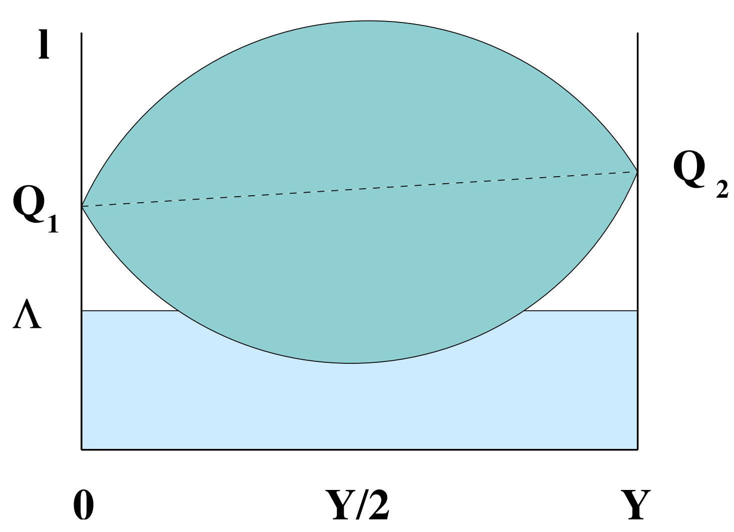
$$\chi(\nu) = \psi(1) - \frac{1}{2}\psi(\frac{1}{2}-i\nu) - \frac{1}{2}\psi(\frac{1}{2}+i\nu)\,, \qquad \psi(\nu) = \frac{\Gamma'(\nu)}{\Gamma(\nu)}\,.$$

Diffusion approximation: $\chi(\nu) \approx 2\ln 2 - 7\zeta(3)\nu^2$,

$$n_p(r, r', Y-y) = \frac{1}{2\pi^2}\frac{1}{rr'}\sqrt{\frac{\pi}{14\zeta(3)\bar{\alpha}_s\, d\,(Y-y)}}\, e^{(\alpha_P - 1)(Y-y)}\, e^{-\frac{\ln^2 \frac{r}{r'}}{14\zeta(3)\bar{\alpha}_s\, d\,(Y-y)}} \,.$$

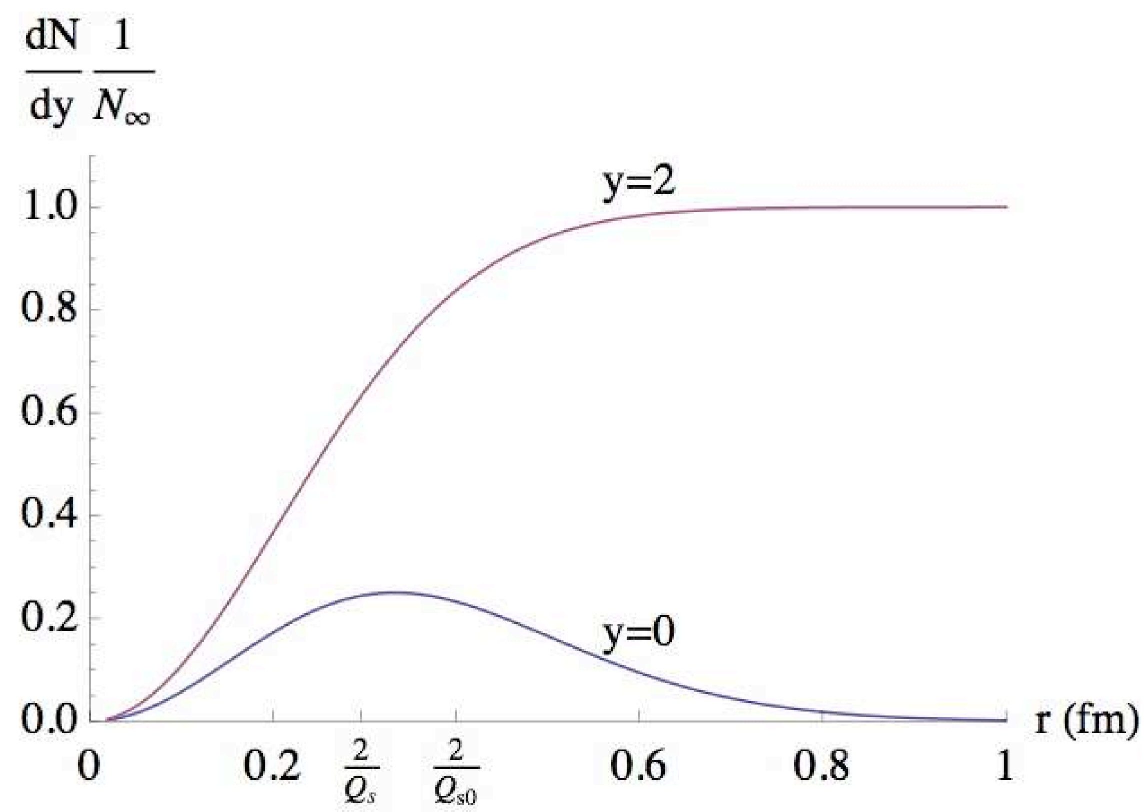
$$\alpha_s(Y-y) \gg \ln^2 \frac{r}{r'}$$

For large enough (Y-y) (corresponding to central and backward rapidities at RHIC), BFKL evolution produces dipoles of various sizes.



Particularly, there appear many dipoles of smaller size $r \ll 1/Q_s$ ⇒ no suppression!

Effect of evolution on diffractive hadron multiplicity

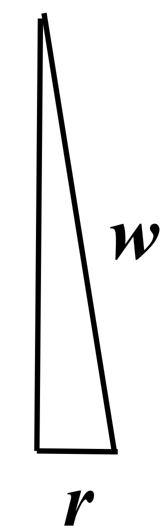


Evolution in nucleus

$N(\mathbf{r},\mathbf{b},y)$ satisfies the BK equation with the initial condition $\quad N(\mathbf{r},\mathbf{b},0)=1-e^{-\frac{1}{8}\mathbf{r}^2\,Q_{s0}^2}\,.$

<u>Linear regime</u> $\quad rQ_s \ll 1$

$$N(\mathbf{r},\mathbf{b},y)_{LT}=\frac{1}{8\pi}\int_{-\infty}^{\infty}d\nu\, e^{2\bar{\alpha}_s\chi(\nu)y}\,(rQ_{s0})^{1+2i\nu}\,\frac{1+(1-2i\nu)\ln\frac{Q_{s0}}{\Lambda}}{(1-2i\nu)^2}\,.$$



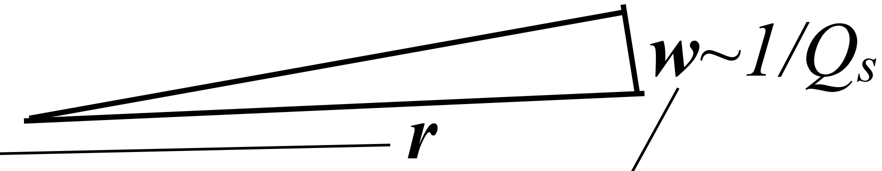
Diffusion approximation

$$N(\mathbf{r},\mathbf{b},y)_{\rm diff}=\frac{rQ_{s0}}{8\pi}\sqrt{\frac{\pi}{14\zeta(3)\bar{\alpha}_s y}}\,\ln\left(\frac{Q_{s0}}{\Lambda}\right)\,e^{(\alpha_P-1)y}\,e^{-\frac{\ln^2(rQ_{s0})}{14\zeta(3)\bar{\alpha}_s y}}\,,\qquad \alpha_s y\gg \ln^2\left(\frac{1}{rQ_{s0}}\right)$$

Double-log approximation $\quad \chi(\nu)_{DLA}\approx\dfrac{1}{1-2i\nu}$

$$N(\mathbf{r},\mathbf{b},y)_{DLA}=\frac{\sqrt{\pi}}{16\pi}\frac{\ln^{1/4}\left(\frac{1}{rQ_{s0}}\right)}{(2\bar{\alpha}_s y)^{3/4}}\,r^2Q_{s0}^2\,\left(1+\sqrt{\frac{2\alpha_s y}{\ln\frac{1}{rQ_{s0}}}}\,\ln\frac{Q_{s0}}{\Lambda}\right)\,e^{2\sqrt{2\bar{\alpha}_s y\ln\frac{1}{rQ_{s0}}}}\qquad \ln\frac{1}{rQ_{s0}}\gg\alpha_s y$$

<u>Gluon saturation regime</u>



$$\frac{\partial N(\mathbf{x}-\mathbf{y},\mathbf{b},y)}{\partial y} = \frac{\alpha_s N_c}{2\pi^2}\int d^2z\,\frac{(\mathbf{x}-\mathbf{y})^2}{(\mathbf{x}-\mathbf{z})^2(\mathbf{y}-\mathbf{z})^2}\left[N(\mathbf{x}-\mathbf{z},\mathbf{b},y)+N(\mathbf{y}-\mathbf{z},\mathbf{b},y)-N(\mathbf{x}-\mathbf{y},\mathbf{b},y)-N(\mathbf{x}-\mathbf{z},\mathbf{b},y)N(\mathbf{y}-\mathbf{z},\mathbf{b},y)\right]$$

$$\frac{\partial N(\mathbf{r},\mathbf{b},y)}{\partial y} \approx \frac{\alpha_s C_F}{\pi}\,2\int_{1/Q_s^2}^{r^2}\frac{dw^2}{w^2}\left[N(\mathbf{w},\mathbf{b},y)-N(\mathbf{w},\mathbf{b},y)N(\mathbf{r},\mathbf{b},y)\right]$$

$$-\frac{\partial\{1-N(\mathbf{r},\mathbf{b},y)\}}{\partial y} \approx \frac{\alpha_s C_F}{\pi}\,2\int_{1/Q_s^2}^{r^2}\frac{dw^2}{w^2}\{1-N(\mathbf{r},\mathbf{b},y)\} = \frac{2\,\alpha_s C_F}{\pi}\ln(r^2Q_s^2)\,\{1-N(\mathbf{r},\mathbf{b},y)\}$$

Define the scaling variable $\tau = \ln(r^2 Q_s^2)$

$$N(\mathbf{r},\mathbf{b},y) = 1 - S_0\,e^{-\tau^2/8} = 1 - S_0\,e^{-\frac{1}{8}\ln^2(r^2Q_s^2)}\,, \quad r \gg \frac{1}{Q_s}$$

Levin, KT, 99

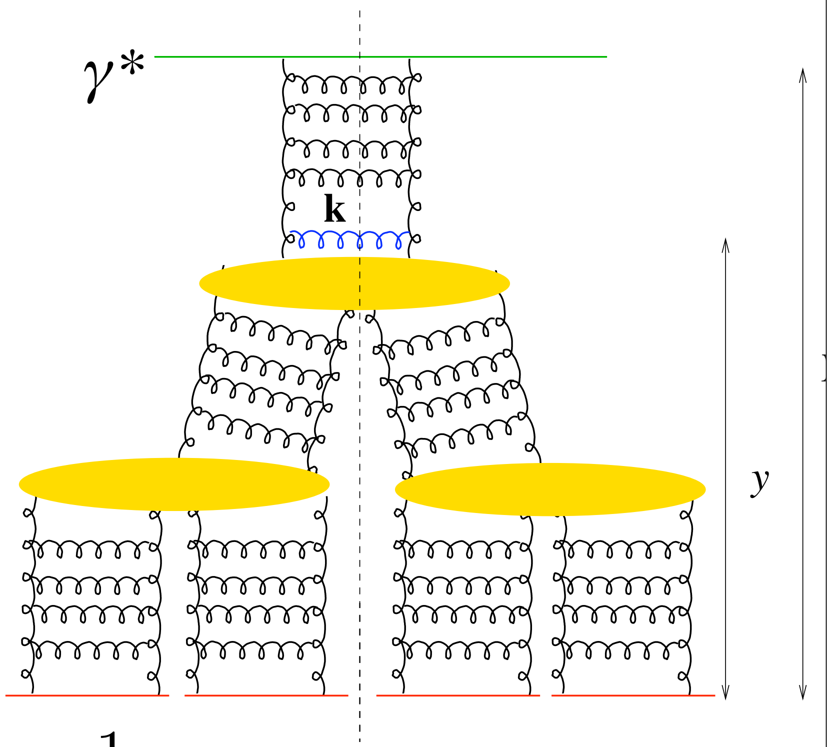
Possible kinematic regions:

- Small onium $r \ll Q_S$
- Large onium $r \gg Q_S$
- Hard gluon $k_T \gg Q_S$
- Soft gluon $k_T \ll Q_S$

Emission of hard gluons by large onium $\mathbf{r}$

$$\frac{d\sigma}{d^2k\, dy} = \frac{\alpha_s C_F}{\pi^{5/2}} \frac{1}{k^2} S_A\, N^2(k^{-1}\hat{\mathbf{k}}, \mathbf{b}, y)\, \frac{1}{(2\bar{\alpha}_s(Y-y)\ln(rk))^{1/4}}\, e^{2\sqrt{2\bar{\alpha}_s(Y-y)\ln(rk)}}, \quad r > \frac{1}{Q_s} > \frac{1}{k}$$

$\propto 1/k^6$ high twist!



Emission of soft gluons by large onium $\mathbf{r}$

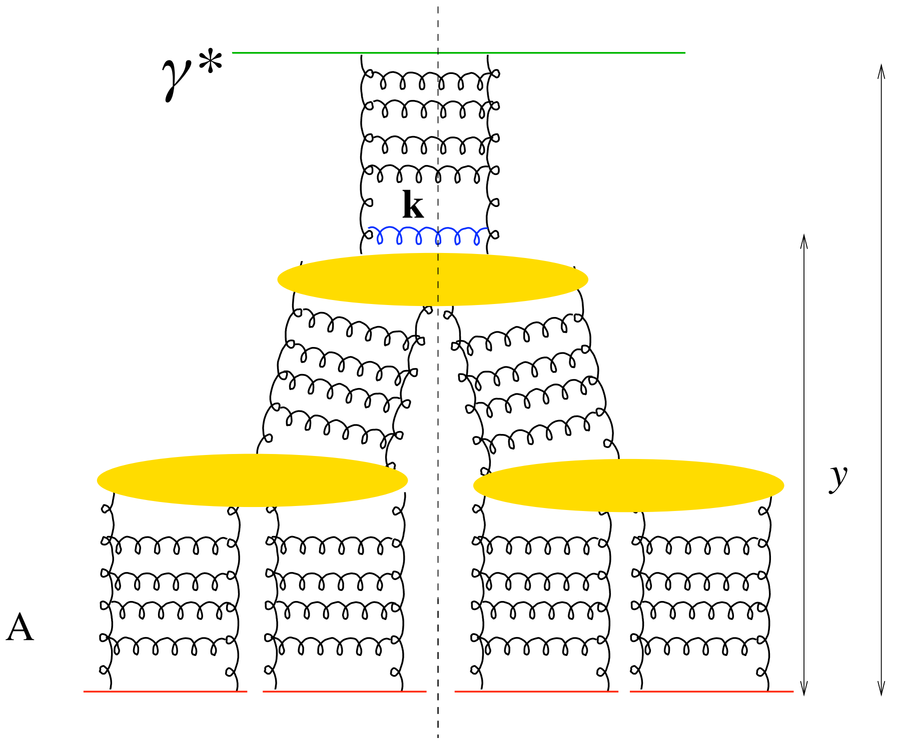
$$\frac{d\sigma}{d^2k\, dy} = \frac{\alpha_s C_F}{8\pi^{5/2}} \frac{S_A}{Q_s^2} \frac{(2\bar{\alpha}_s(Y-y))^{1/4}}{\ln^{3/4}(rQ_s)}\, e^{2\sqrt{2\bar{\alpha}_s(Y-y)\ln(rQ_s)}}, \quad r, \frac{1}{k} > \frac{1}{Q_s}$$

Multiplicity comes from the cut Pomeron connecting the incident onium and the daughter dipole r’

Emission of hard gluons by small onium $\mathbf{r}$

$$\frac{d\sigma}{d^2k\,dy} = \frac{\alpha_s C_F}{\pi^{5/2}}\, S_A\, r^2\, N^2(k^{-1}\hat{\mathbf{k}}, \mathbf{b}, y)\, \frac{1}{\left(2\bar{\alpha}_s (Y-y) \ln \frac{1}{kr}\right)^{1/4}}\, e^{2\sqrt{2\bar{\alpha}_s (Y-y)\ln\frac{1}{kr}}}\,, \qquad r < \frac{1}{k} < \frac{1}{Q_s}$$

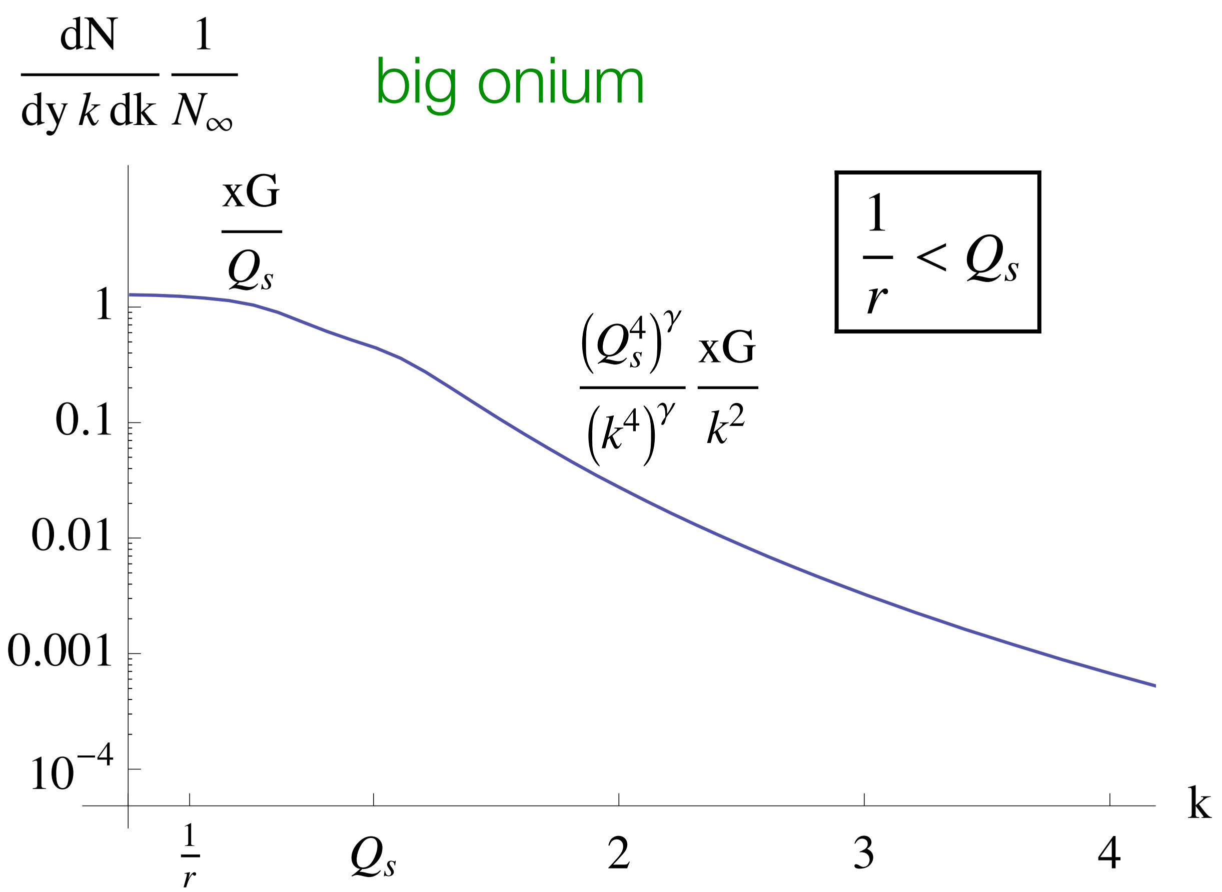
Color transparency

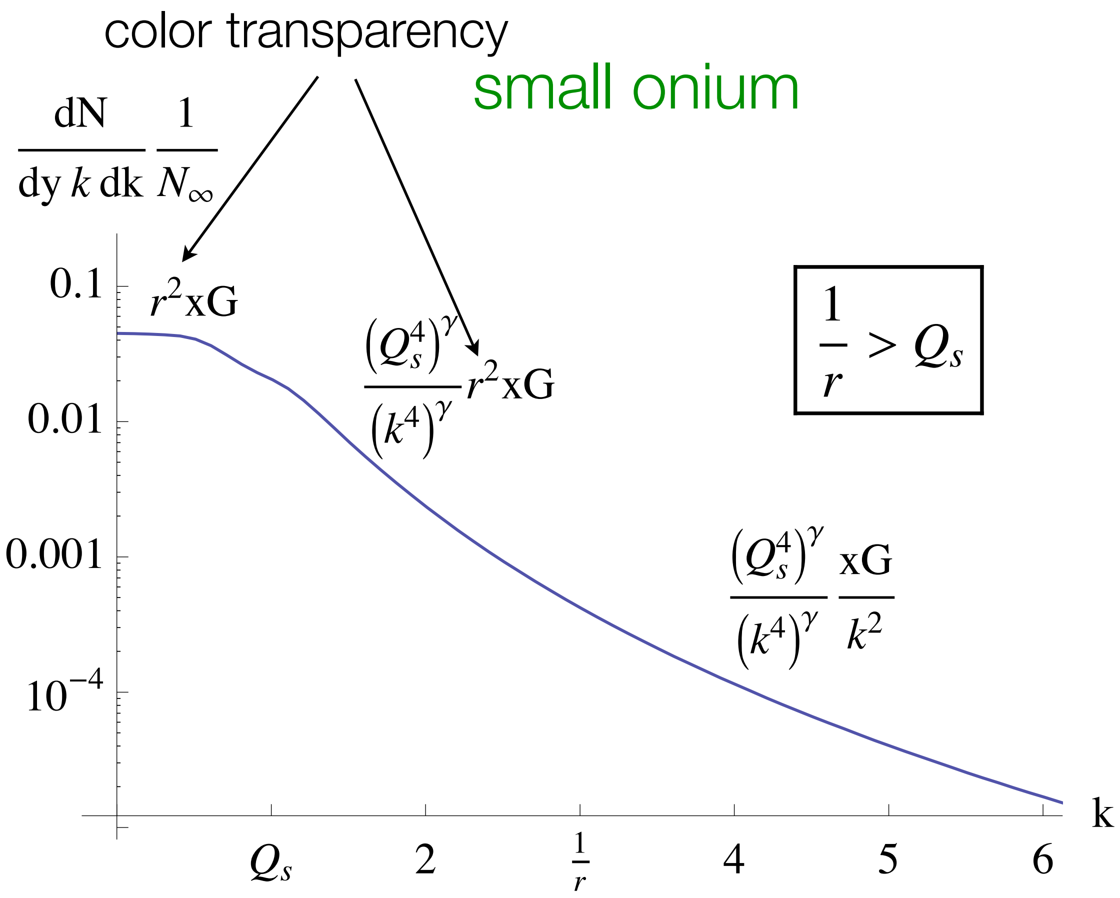


Emission of soft gluons by small onium $\mathbf{r}$

$$\frac{d\sigma}{d^2k\,dy} = \frac{\alpha_s C_F}{4\pi^{5/2}}\, S_A\, r^2\, \frac{1}{\left(2\bar{\alpha}_s (Y-y) \ln \frac{1}{rQ_s}\right)^{1/4}}\, e^{2\sqrt{2\bar{\alpha}_s (Y-y)\ln\frac{1}{rQ_s}}}\,, \qquad r < \frac{1}{Q_s} < \frac{1}{k}$$

Diffractive gluon spectrum: Summary





In the geometric scaling region: $\gamma \approx 1/2$, in hard perturbative QCD $\gamma \sim 1$ ⇒

different dependence on $Q_s(y,A)$ in different kinematic regions

Nuclear dependence

"Nuclear modification factor": $R^{OA}(k,y) = \frac{\frac{d\sigma^{OA}(k,y)}{d^2k\,dy}}{A\,\frac{d\sigma^{OP}(k,y)}{d^2k\,dy}}$

pQCD limit (DLA): $$R^{pA}(k,y) = \frac{S_A}{A\,S_p}\sqrt{\frac{\ln\frac{k}{Q_{s0}}}{\ln\frac{k}{\Lambda}}}\,\frac{Q_{s0}^4}{\Lambda^4}\left(1+\sqrt{\frac{2\bar{\alpha}_s y}{\ln\frac{k}{Q_{s0}}}}\right)^2 e^{4\sqrt{2\bar{\alpha}_s y}\left(\sqrt{\ln\frac{k}{Q_{s0}}}-\sqrt{\ln\frac{k}{\Lambda}}\right)}, \quad k \gg Q_g$$

$$R^{pA}(k,y) \approx A^{1/3}\left(1 - 32\,\bar{\alpha}_s\,y\,\frac{\ln\frac{Q_{s0}}{\Lambda}\,\ln\frac{k}{Q_{s0}}}{\ln\frac{k}{\Lambda}}\right)$$

enhancement since it's a higher twist!

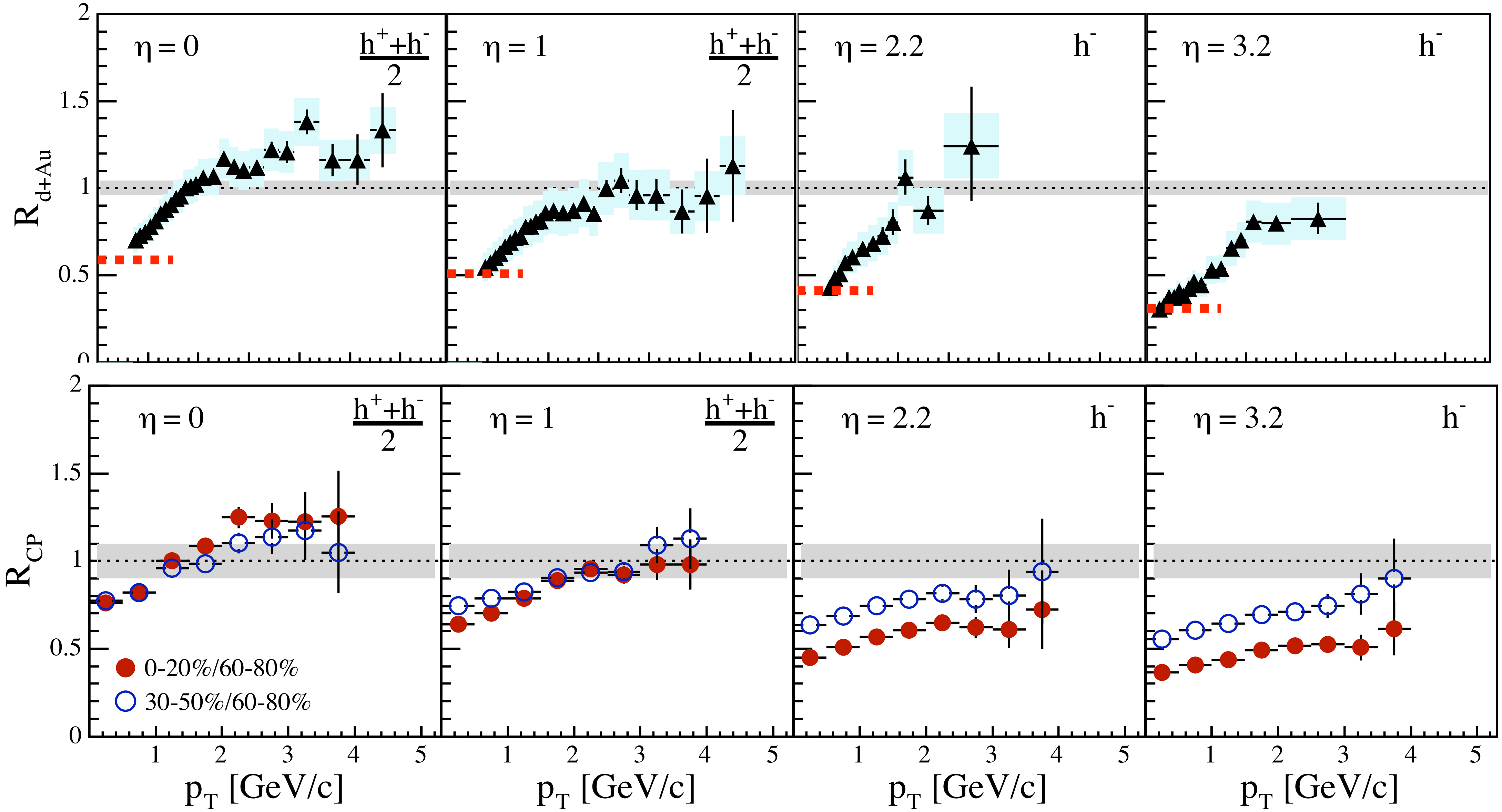
Geometric scaling region (LLA): $$R^{pA}(k,y) = \frac{1}{7\zeta(3)}\,\frac{k^2}{\Lambda^2}\,\frac{\ln^2\left(\frac{Q_{s0}}{\Lambda}\right)\sqrt{2\bar{\alpha}_s y}}{\sqrt{\ln\frac{k}{\Lambda}}}\,\exp\left\{2(\alpha_P-1)y - 4\sqrt{2\bar{\alpha}_s y\ln\frac{k}{\Lambda}} - \frac{2\ln^2\left(\frac{Q_{s0}}{k}\right)}{14\zeta(3)\bar{\alpha}_s y}\right\}$$

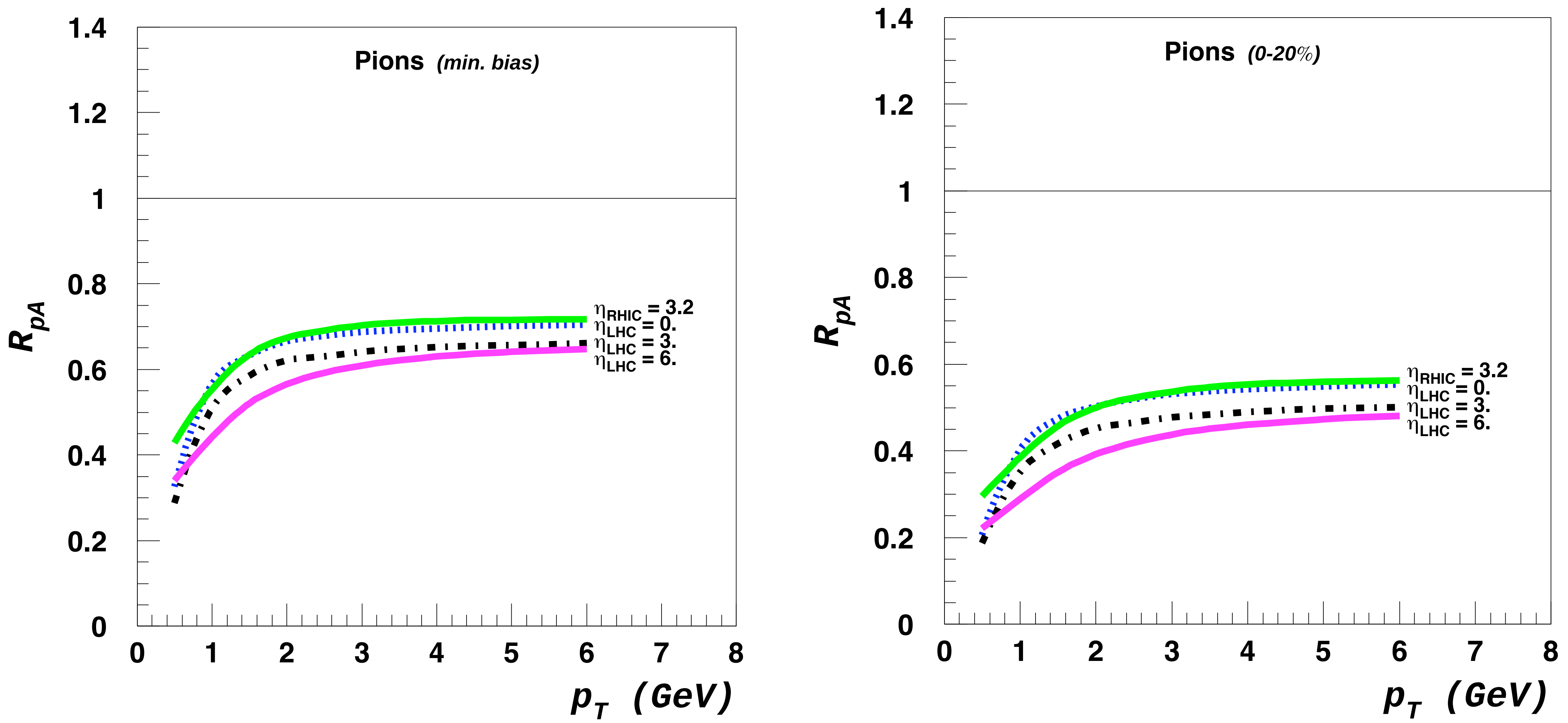
no A dependence!

$$R^{pA}(Q_g(y),y) \sim A^{1/3}\,e^{-4\sqrt{\bar{\alpha}_s\lambda}\,y}$$

suppression at higher energies/rapidities

Comparing diffractive and inclusive production

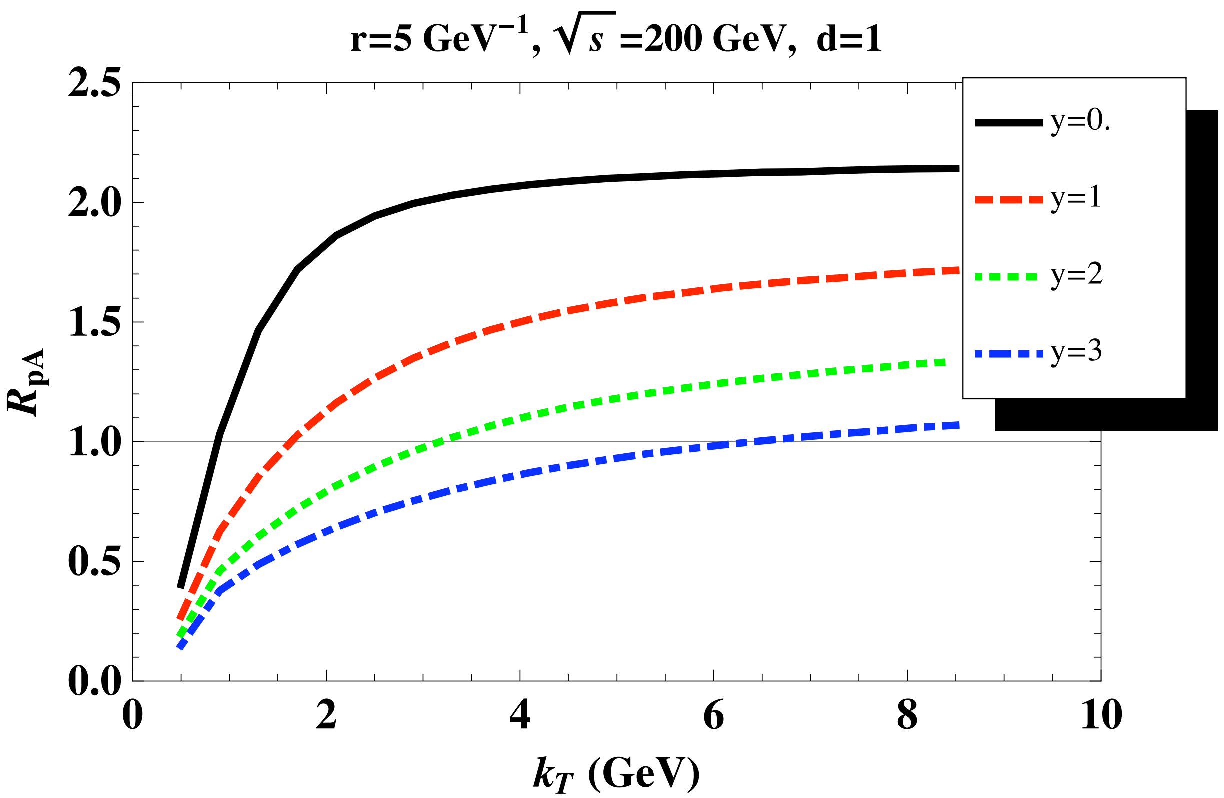




KT, 2007

Inclusive gluon production at not very high momenta is expected to be rather trivial ... unlike the diffractive production

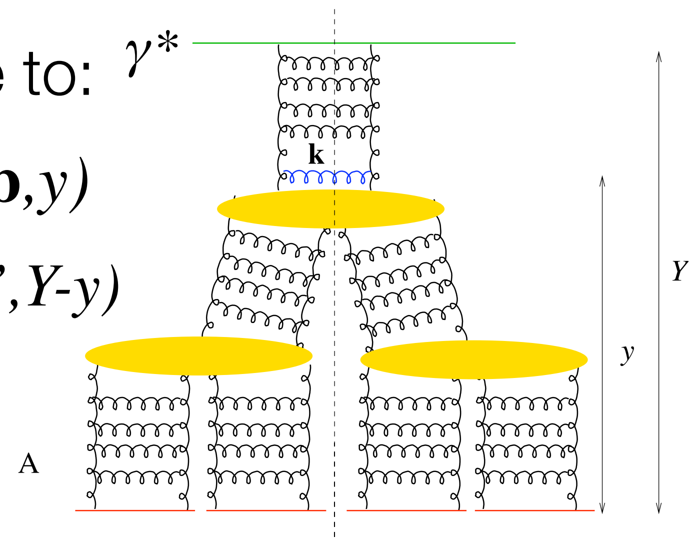
Large dipoles at RHIC energy



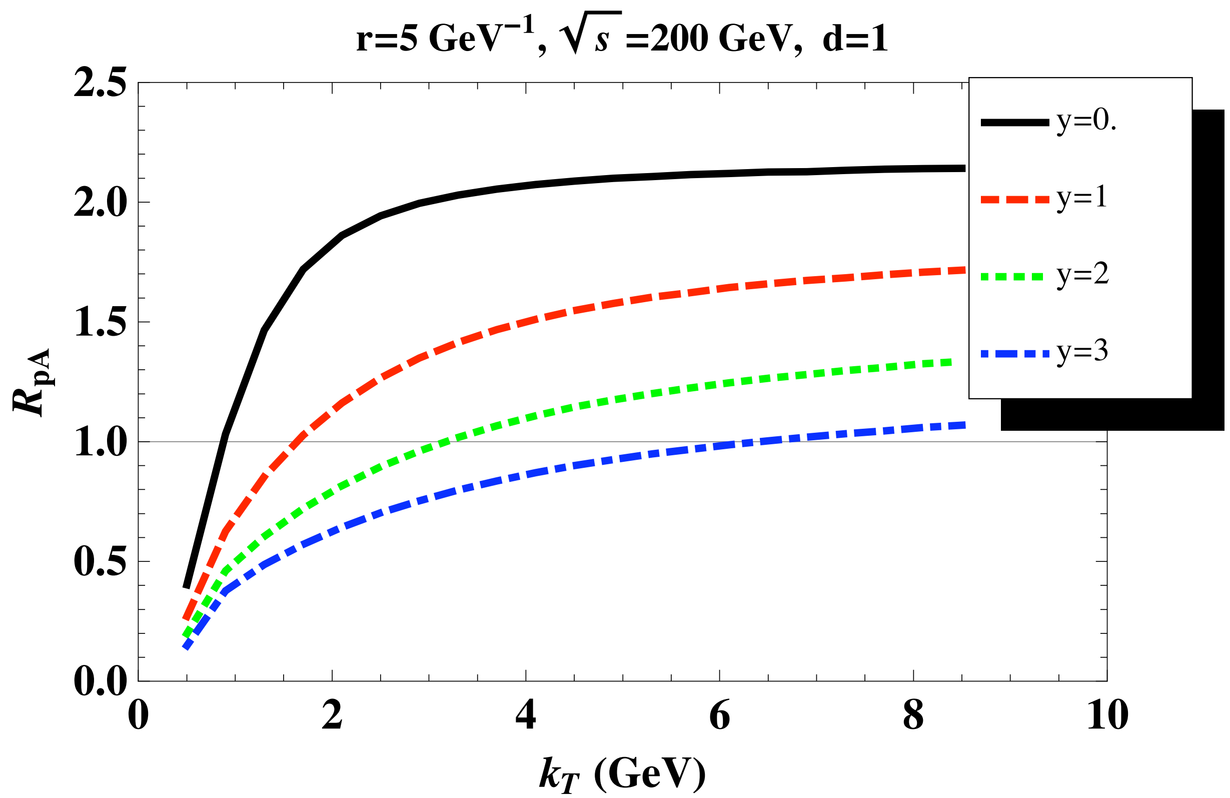
Decrease with y is due to:

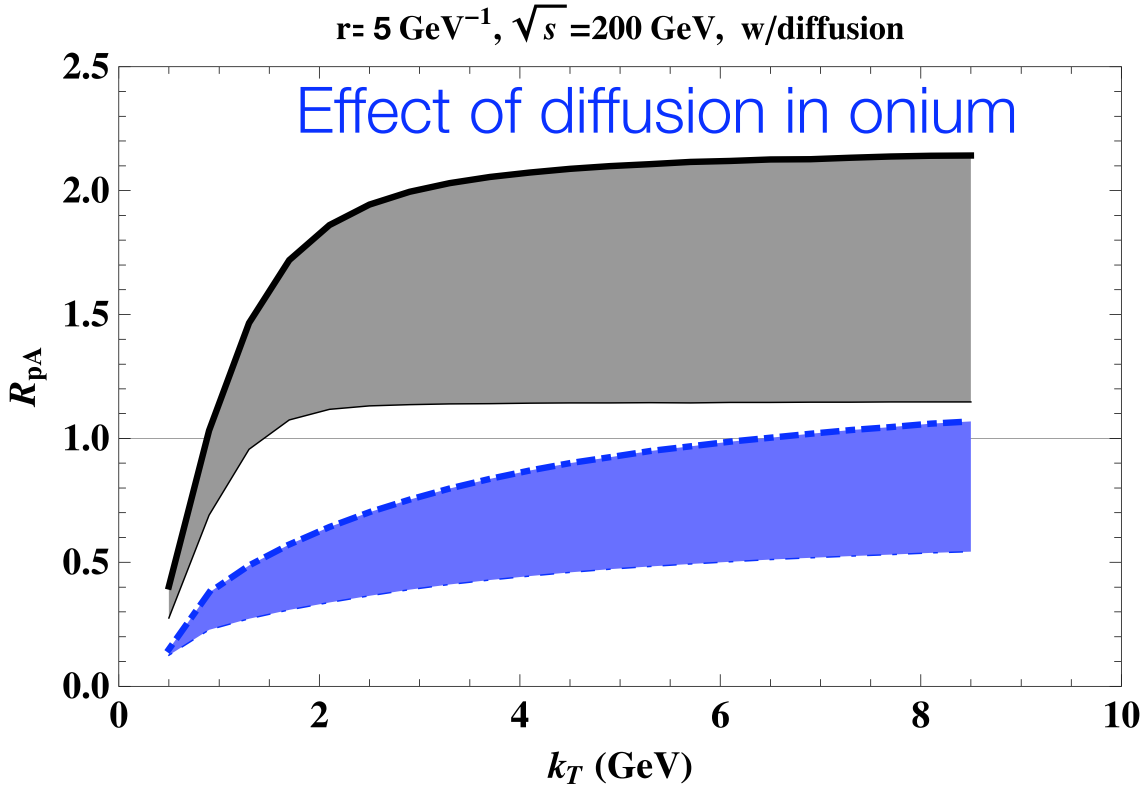
1) unitarization of $N(\mathbf{r}',\mathbf{b},y)$

2) less diffusion in $n(\mathbf{r},\mathbf{r}',Y-y)$



Large dipoles at RHIC energy





Decrease with y is due to:

1) unitarization of $N(\mathbf{r}',\mathbf{b},y)$

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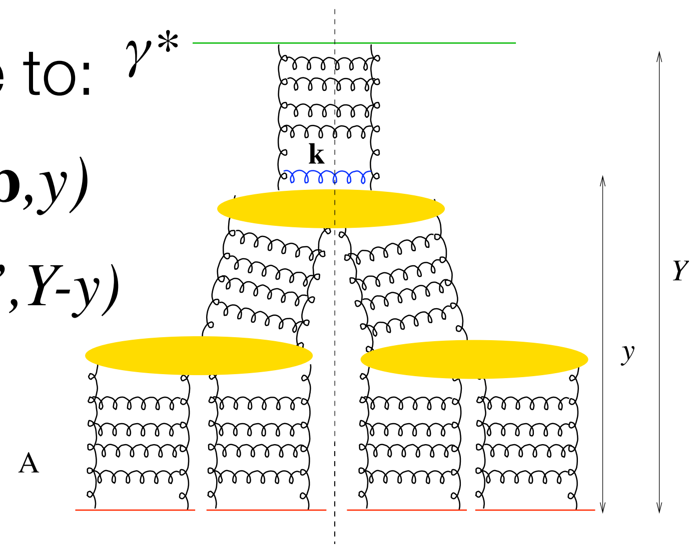
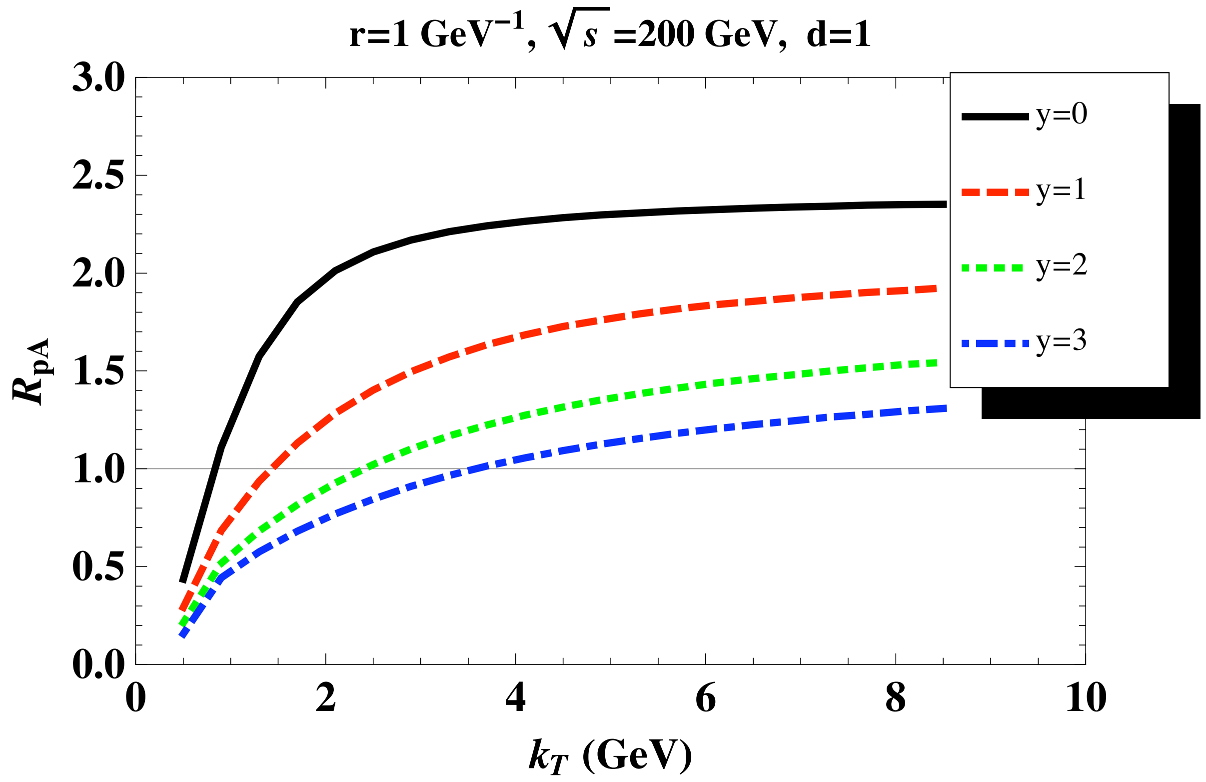


$$n_p(\mathbf{r},\mathbf{r}',y) \propto \exp\left\{-\frac{\ln^2(r'/r)}{14\zeta(3)\,d\,\bar{\alpha}_s y}\right\}$$

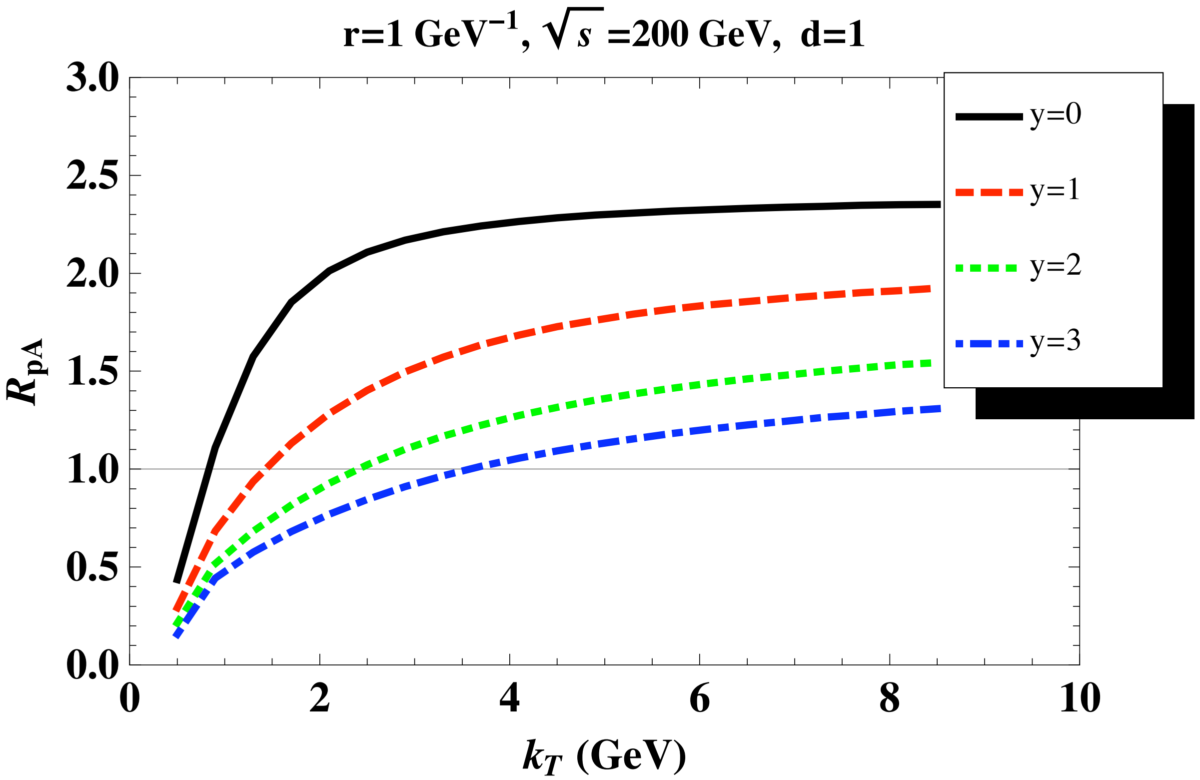
Suppression of diffusion can be indicative of the gluon saturation in onium.

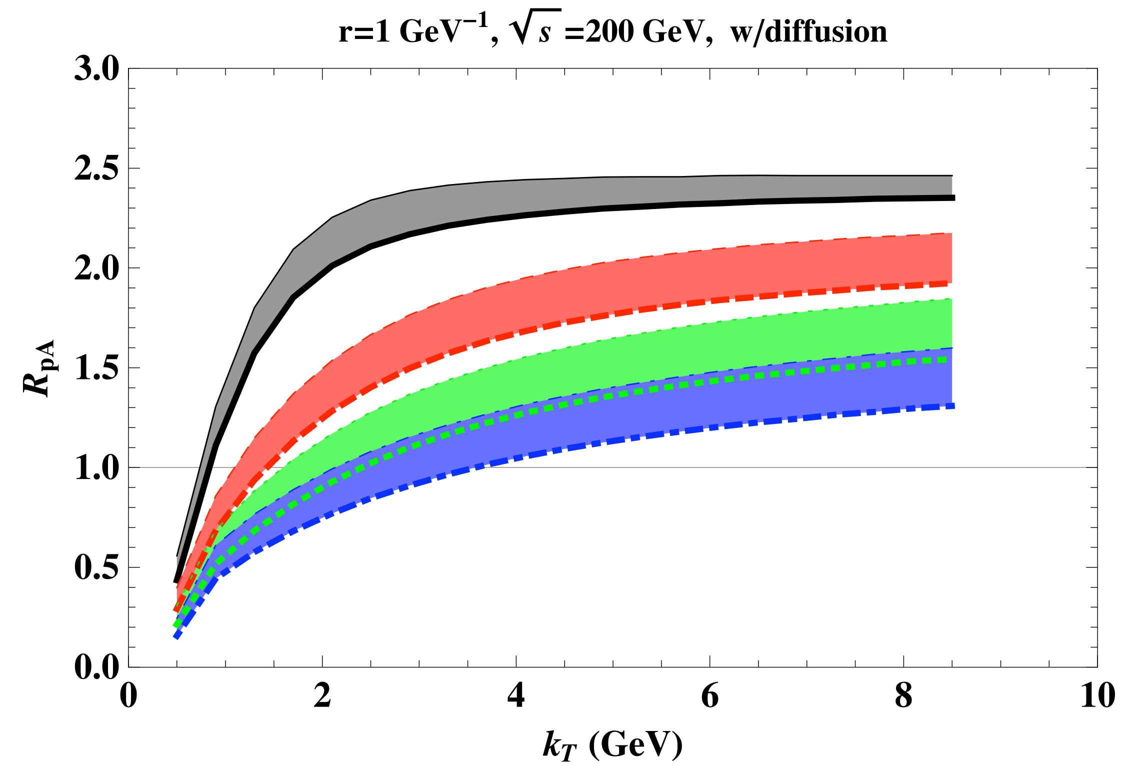
Small dipoles at RHIC energy



Small dipoles are much less sensitive to the details of the low-x evolution in *onium*

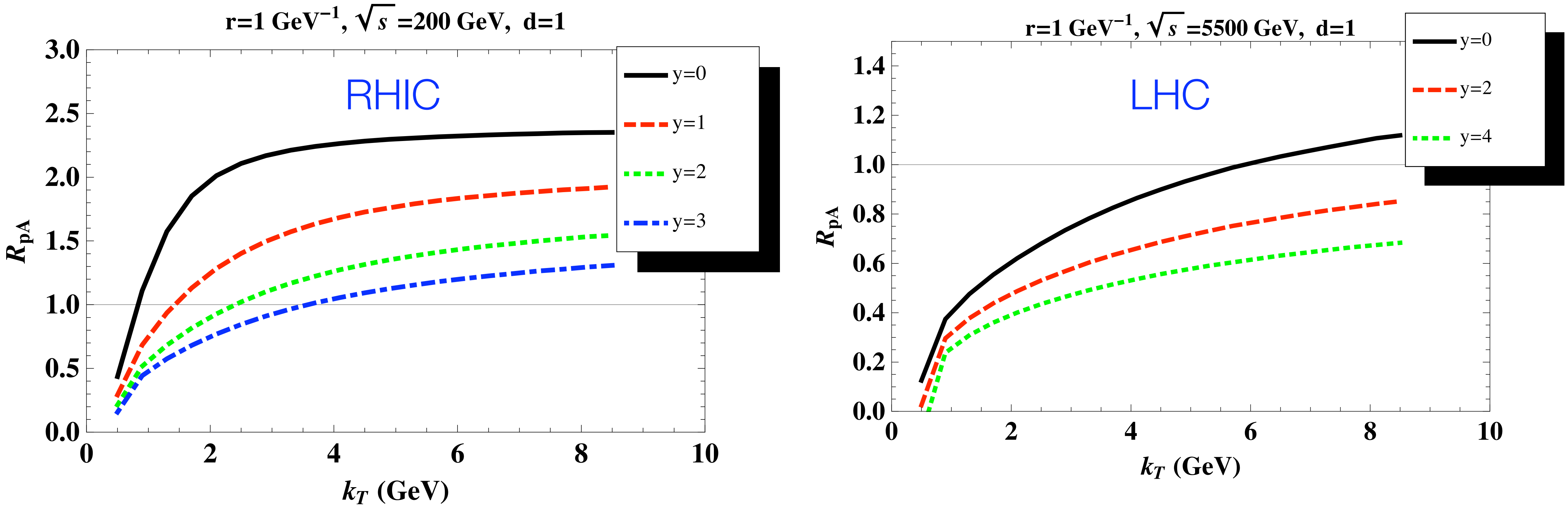
Small dipoles at RHIC energy





Small dipoles are much less sensitive to the details of the low-x evolution in *onium*

RHIC vs LHC



r=1 GeV^{-1}, $\sqrt{s}$ =200 GeV, d=1
RHIC
y=0
y=1
y=2
y=3
R_{pA}
k_T (GeV)
r=1 GeV^{-1}, $\sqrt{s}$ =5500 GeV, d=1
LHC
y=0
y=2
y=4
R_{pA}
k_T (GeV)

Summary

1. Diffractive gluon production in eA and pA collisions has remarkable sensitivity to the low-x dynamics in onium and nucleus.

2. Dependence on r, y, A and k provide a convenient handles on behavior of gluon densities in various kinematic regions.

3. It can become a valuable tool for pA and DIS phenomenology at RHIC, LHC and EIC.